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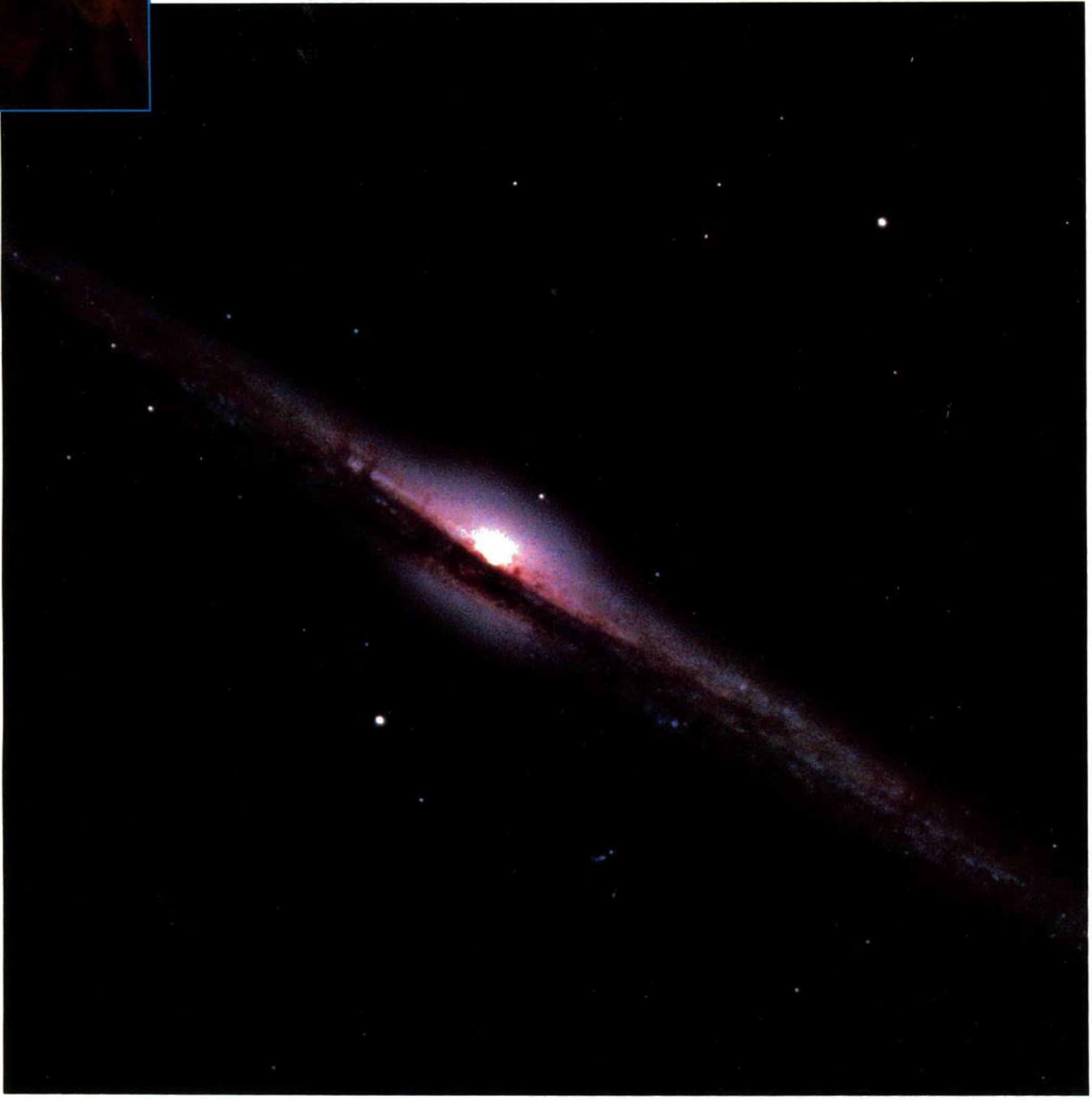

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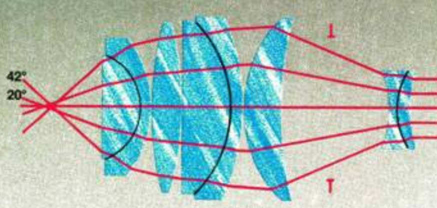


Optical design of Meade Ultra Wide Angle eyepieces.

"Several hundred amateurs had the chance to test the performance of Meade Series 4000 eyepieces at the Astrofest Telescope Convention. Observing Jupiter with your Ultra Wide 8.8mm on a 7″ f/9 Starfire refractor, the huge 84° field encompassed the entire Jovian system. The four moons were resolved as discs, perfectly round even at the extreme edge of the field. Jupiter itself presented a magnificent show with a multitude of bands, small ovals, and festoons, etched in high contrast on the planet's surface. Meade Ultra Wide Angle eyepieces are a unique design that really brings out the best in a high performance telescope."

—**Roland Christen,** President, Astro-Physics Corp., Rockford, IL

Meade® SC Optic

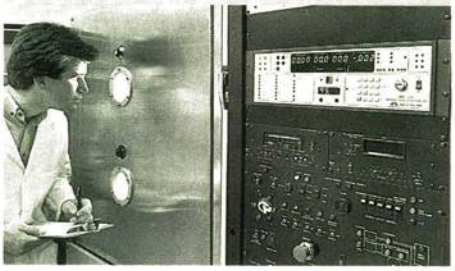
Keeping up with modern optical technology is an expensive process at Meade Instruments—but one which is absolutely vital to our continuing leadership in the production of Schmidt-Cassegrain optical systems. Long recognized as the finest commercially-produced Schmidt-Cassegrain optical systems available, Meade SC optics have recently been still further refined by the addition of important new equipment and processes—additions that assure the potential Meade SC purchaser that his or her telescope is, without qualification, state of the art.

New Super Multi-Coating (SMC): Now included as standard equipment on the correcting plates of most Meade 4″, 8″, and 10″ SCT models, the deep-purple Super Multi-Coating produces the highest light transmission of any antireflection coating in the industry.

Super Multi-Coating on the Meade 8″ 2080/Model 50.

At our Costa Mesa coating facility, Meade technicians use the latest electron beam vacuum coating systems to deposit, at 550°F, the hard, multi-layer chemistry of the SMC—a coating that perceptibly increases image brightness and contrast. Seven correcting plates can be coated on one plate side simultaneously; the plates are then automatically flipped internal to the vacuum system to permit coating of the opposite surfaces.

Electron beam vacuum coater.



"I have been absolutely delighted with the superior performance of the Meade 10″ Schmidt-Cassegrain. The optics are superb. At a recent star party Omega Centauri was resolved into thousands of tiny pinpoints into its core...Many said they were thrilled not only to see so much spiral structure in the Whirlpool Galaxy (M51) but also to see the faint bridge between the two components of M51."

—**L. J. Alfonso,** Boca Raton, FL

Primary Mirror Central Coring: Before Meade 4″, 8″ and 10″ SC primary mirrors can be polished and figured to within exacting optical tolerances, the central perforation, or

al Performance..."Superior...Superb...Breathtaking."

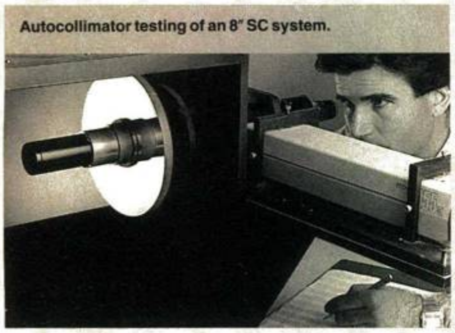
core, of each mirror blank must be precision diamond-ground into the blank. In the Meade optical shaping department this operation is performed on a 5-axis Computer Numerically Controlled (CNC) glass-machining center. The result is a mirror perforation (ready to accept the primary mirror baffle and focusing mechanism) that is within arc minutes of perfection—a precision that, with minor final adjustment by optical alignment technicians *(see below)*, virtually eliminates mechanically induced aberrations in the Schmidt optics.

CNC coring of SC primary mirrors.

"When unpacking my Meade 10" SCT I realized that the amount of work which had gone into making this instrument was incredible...every detail was perfect down to the last nut and bolt. On the first clear night I took the scope out to check the optics. Quite simply the views were breathtaking! Star images matched textbook versions letter for letter, showing perfect symmetry in and out of focus."
—J. Spang, Chorely, England.

Optical Testing: As each Meade 3-element SC optical set (primary mirror, secondary mirror, and correcting plate) progresses through the grinding, polishing, and final hand-matching stages of development, it is continuously tested and re-tested for zonal irregularities, smoothness, and correction. Intermediate testing is performed using the Foucault and Ronchi methods; final diffraction image testing is done with a double-pass laser autocollimator that passes an intense pinhole of monochromatic light through the 3-element system *twice*, enabling the technician to detect errors (at an effective magnification of 1000X) beyond the observable limit of the field user. If we seem unusually confident in the capabilities of Meade Schmidt-Cassegrain optics, it is because we know that every optical set is put through this battery of over 30 separate optical tests and inspections before the optics are mounted in the optical tube and shipped to you.

Autocollimator testing of an 8" SC system.



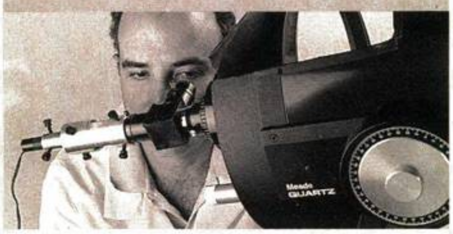
"Using my Meade 8" SCT under just fair seeing the 1.0 arc sec double Zeta Boötes was beautifully separated, with plenty of dark space between the circular Airy discs. At lower power the four stars of Epsilon Lyrae were also cleanly separated and a beautiful sight, with all in the same field."
—R. Knight, Stow, OH

Interferometric testing of diagonal flats.

Diagonal Flat Testing: Integral to the functioning of any high-performance Cassegrain system is the optical smoothness and flatness of the diagonal surface. Every Meade diagonal mirror is tested for flatness on a Fizeau laser interferometer; mirrors which pass this test are coated with enhanced aluminum and mounted in their machined diagonal housings.

Optical Alignment: Finished, individually matched 4", 8" and 10" SC optical sets are sent to the optical alignment department, where each set is placed into a special cut-out optical tube that permits rotation of the optical elements about the optical axis. (The relative rotational orientations of the Schmidt-Cassegrain primary mirror, secondary mirror, and correcting plate are *not* arbitrary.) Rotation of the optics, while the technician observes an artificial starpoint under controlled laboratory conditions at high power, yields the unique relative orientation that cancels out any residual aberrations of the system. With optimal orientation thus fixed, each optics set is placed into the machined housings of its optical tube. The optical system is once again tested for roundness, regularity, and consistency of the diffraction image inside and outside of focus. Only after passing this final test is an optical tube system ready to become part of a Meade Schmidt-Cassegrain telescope.

Rotational orienting of 10" SC optics.



"As a former staff member at Mt. Wilson and Palomar Observatories, I have had access to some of the finest optics ever produced. The Meade 10" f/6.3 2120 is the most impressive commercial instrument I have yet seen. Under critical examinations, stellar diffraction patterns are superb both inside and outside of focus. Focal images are sharp and crisp; in applications where high contrast characteristics are important (such as in observing the 'eyes' of the Owl Nebula, M97, or structural variations in the main spiral arm of the Whirlpool Galaxy, M51) the telescope performs impressively. The image of Saturn is beautifully defined, showing subtle belt detail and the crepe ring with surprising boldness for a 10" telescope."
—Paul Roques, Williams, AZ

Final quality control inspection.

Quality Control: As part of the final quality control inspection, an inspection which also includes detailed checkout of the telescope's mechanical and electronic functioning, each optical system is examined for any coating sleeks or scratches which may have occurred in the manufacturing process. Telescopes which pass this series of tests are then packed for shipment to authorized Meade dealers throughout the world.

Every Meade Schmidt-Cassegrain telescope must pass more than 135 optical, mechanical, and electronic tests, inspections, and quality control procedures before it is judged ready for shipment. If you're as committed to optical quality and performance as we are, then see what a Meade 4," 8," or 10" Schmidt-Cassegrain can do for your observing program. See the telescopes that combine the finest, most integrated electromechanical systems, including the revolutionary Smart Drive,™ with the highest level of optical precision in the industry today.

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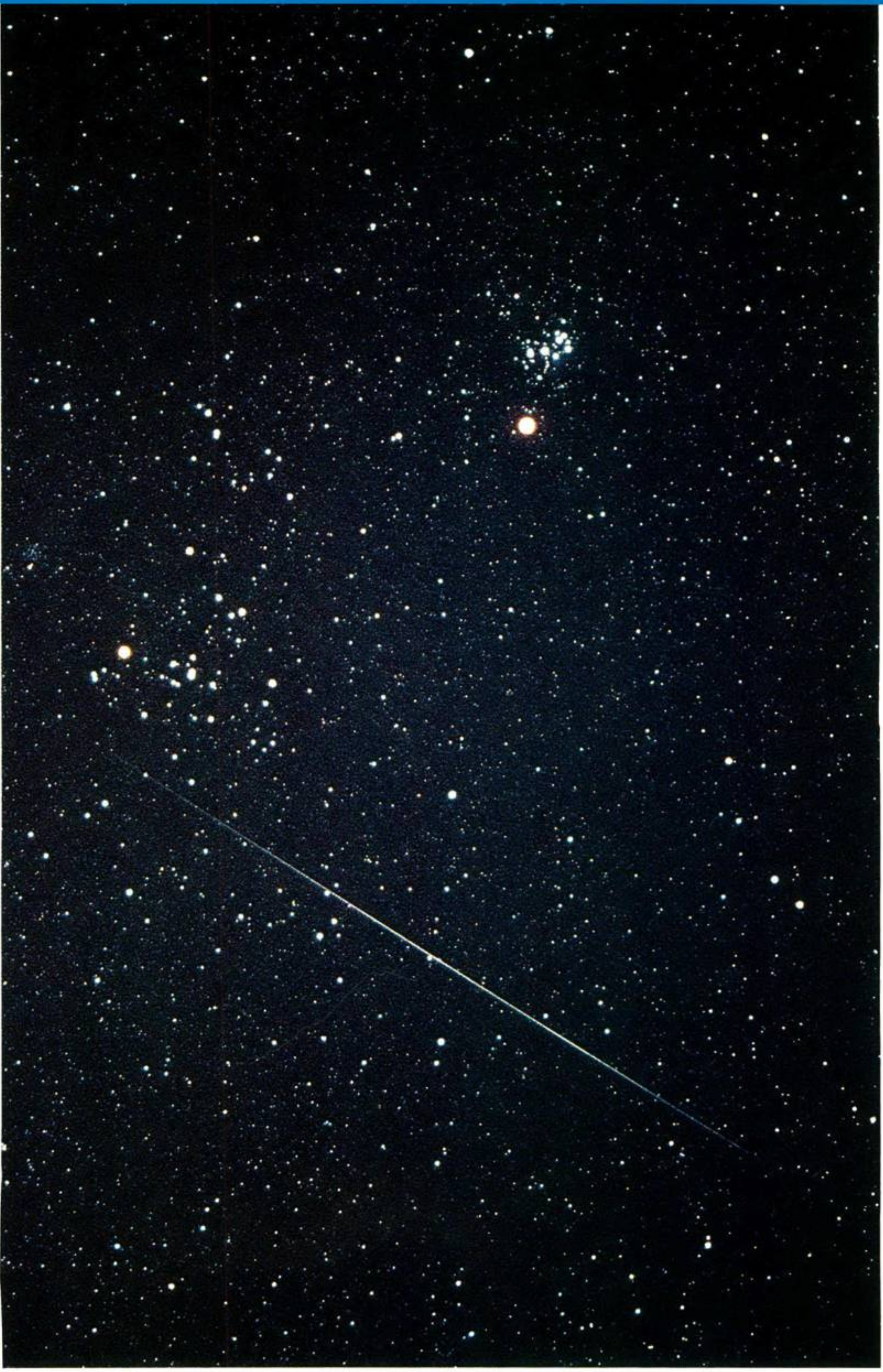
ON THE COVER:
A needle in the sky, the spiral galaxy NGC 4565 is one of the telescopic attractions of Coma Berenices. For a tour of this spring constellation, see page 80. Photo courtesy Canada-France-Hawaii Telescope Corporation, T. Gregory, photographer.



PIERCING THE NIGHT, a Geminid meteor streaks through Taurus below Mars and the Pleiades. This 2-minute guided exposure was taken December 13 during last year's active Geminid meteor shower. Photo by Terence Dickinson.

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The Audit Bureau

Behind the Scenes

EARTH LAUNCH A SUCCESS

In early January, EARTH magazine went on sale at newsstands worldwide. Simultaneously, thousands of copies were bundled onto trucks, bound for the homes of new EARTH subscribers. Meanwhile, in the mailroom here at Kalmbach, employees opened direct-mail orders for EARTH.

"I just received the first issue of your new magazine EARTH — it's great! It's technical enough to be informative, yet it is readable and interesting at the same time." Such warm reader feedback makes the years of planning and hard work behind that first issue all the more worthwhile.

The first issue of EARTH was actually produced as a thirteenth issue of ASTRONOMY, and the magazine itself was produced by the ASTRONOMY staff. Robert Burnham served as that issue's editor, and Tom Hunt served as art director. Rhoda Sherwood and Tracy Staedter carried out the proofing, scheduling, and production work, and designer Jane Lucius helped with the look of EARTH. During those hectic months, ASTRONOMY's other editors had to work twice as hard as normal, too, to help create a new magazine "in our spare time."

EARTH's reception is deeply satisfying to us here at ASTRONOMY because we believe that EARTH fills a need in our modern world for a vigorous and objective magazine about our planet, a magazine that does for our planet what ASTRONOMY does for astronomy.

But there's a lot more to launching a new magazine than defining an editorial mission. All around Kalmbach, other departments pitched in to make EARTH a reality. In a marathon month of selling, Greg Swan and Cathy Odland sold advertising for a magazine that didn't yet exist. While Kristie Fischer and Charlie Post plotted circulation strategies and publisher Bob Maas worked his magazine finance models, Elaine Paque and her creative staff designed a direct-mail package. Standing behind our efforts and backing us was Walt Mundschau, the president of Kalmbach.

Work is now under way on the first and second issues of EARTH magazine. Steven Zaburunov has joined Kalmbach as the Editor of EARTH, with Judy Katona-Holmes as EARTH's Technical Editor. Both are a pleasure to talk to; their enthusiasm and knowledge of the earth sciences will soon manifest itself in the pages of EARTH.

For those of you who wrote, "Please keep up the fantastic work! I'm really looking forward to the next issue" — our schedule calls for your next issue to be mailed in October. Newsstand copies will go on sale in early November. Please be assured — the wait will be worth it.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

ASTRONOMY

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Letters

Earth and No Moon

Professor Neil Comins' article "The Earth without the Moon" (February issue) was excellent and thoroughly enjoyable. However, at the risk of nitpicking, I should point out an error. Comins stated that "the time between consecutive high tides today is the time it takes the Moon to move from its highest point in the sky to the point above the place exactly on the opposite side of Earth." This seems to mean a place differing from the Moon's highest point in the sky by 180 degrees in right ascension and having a declination of the opposite sign.

In fact, the Moon's declination would be essentially the same. For an observer who saw the Moon pass directly overhead, the Moon would not pass through that observer's nadir half a lunar day later. This appears to be the same sort of misconception that gave rise to the notion that if we Americans dug a hole straight through the Earth it would come out in China! That's wrong. But a Moon that passed through the zenith in Florida passes overhead as viewed from China about 12 hours and 25 minutes later. — *Max J. Irland, New Port Richey, Florida*

Comins wondered if we would all have two sets of eyes (one for infrared viewing) if the Earth had no Moon. Why not long whiskers for feeling our way around, or rubber craniums in case we bumped into something? — *Barry Evans, Palo Alto, California*

Another unusual benefit of having a Moon is that it allowed humans to prove rather efficiently that Earth is a sphere. Without a round Moon this would seem to be substantially more difficult as viewed by the astronomers of past centuries! — *David Thorndill, Baltimore, Maryland*

The Moonless Earth article was a fascinating, original presentation. But the article isn't perfect: it contains an error regarding the dynamics of the Earth-Moon system. We're constantly reminded of the small secular change in Earth's rotation and thus the lengthening of the day — we recently received a leap second because of it. The angular momentum lost by Earth because of friction results in an increase in the Moon's angular momentum, thus causing the Moon to move slowly away from Earth. As it moves away from Earth the Moon's orbital velocity must decrease, not increase as stated in the article.

I think we're fortunate to have a Moon

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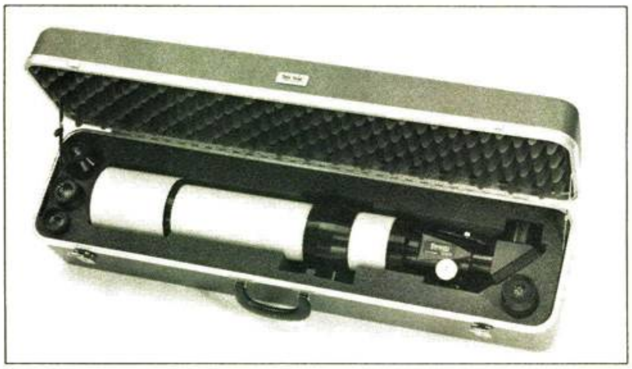

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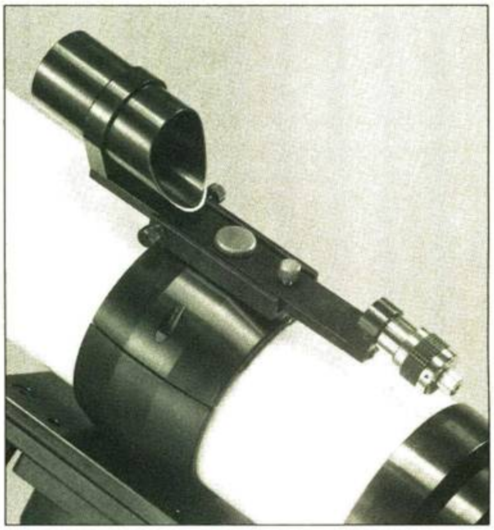

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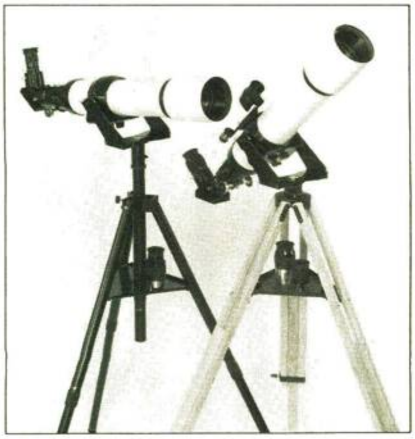

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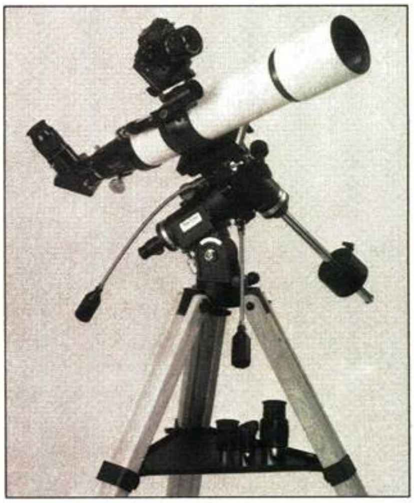

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It makes interesting reading. And lets face it, the chances of getting your letter printed are a lot better if you have a good story. Common sense tells you that if a plain old alkaline battery will power your NGC-MAX for 24 hours, a "Super-Heavy-Duty" carbon zinc battery should work a lot longer, right?

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Manufacturer claims 363 stars, customer claims 241.

The customer is correct. Earlier ads for the original NGC-MAX had 363 stars. In the change-over to the new style, this claim was dropped from our ad as 122 stars were sacrificed so that many other features could be added. What the customer may not have known, is that we added a star chart reference on all of the over 8,000 objects, as well as other features which were included, but never advertised. One such feature was a low battery indicator, as well as a marvelous addition - an indicator which notifies the user of encoder or cable failure. A ROM chip is being offered free-of-charge to owners who purchased their NGC-MAX after May of 1990, to correct mentioned errors. JMI supports customers with warranty service. Your NGC-MAX will not become obsolete since it is designed with an upgradeable ROM memory. We plan to offer ROM upgrades at very reasonable prices.

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- Dr. Shronts, MN

"Wow!...[the NGC-MAX] does everything you say it will do! I can find any deep sky object I want in 30 seconds! When I am at a star party...there is a constant parade of people coming by my telescope to ask me to find various deep sky objects."

- W. Maguire, CA

"I still can't believe how great the 'MAX' works. Mine is certainly getting an incredible workout."

- T. Randall, NY

"I am very satisfied with all of your service and quality engineering that makes my telescope up-to-date for the year 2000 technology."

- Craig Neun, PA

"It's [NGC-MAX] been great. Helped immensely in my telescope use. I couldn't find anything before."

- Dr. G.F., NH

REVIEWING THE NGT IN THE MARCH ISSUE OF ASTRONOMY

We appreciate the reviews, we think it is an excellent service to the reader. As a result of the reviews, we get inquiries such as:

"Was the review accurate?" "Do you think it was fair?"

We were amused by the fact that the "NGT" came out of the review with a new connotation. What was the Next Generation is now reported to be the New Generation Telescope! Not bad - we are wondering why we didn't think of it!

The review stated that re-collimation was required after installing the mirror cell. We have found that just the opposite is true - and another review corroborates this. We feel very sure that the reviewer did not get the mirror cell indexing pins properly indexed with the tub.

The actual size of the diagonal's minor axis is 4 inches, not the reported 4-1/2.

Jim's Mobile Inc. welcomes comments and suggestions from customers. We are constantly improving our products so that our customers get the best value and quality.

Jim Burr, President

where it is now, or we wouldn't be in for a spectacular show this July. — *Lon Caracappa, Boston, Massachusetts*

Life near the Center of the Galaxy

I want to compliment Neil Comins on his article "Life near the Center of the Galaxy" (April issue). I was somewhat startled at the number of assumptions and speculations bandied about by a respected physicist and then remembered a class of thinking I used to call "speculative astronomy." I would call Comins' piece informed science fiction, and I think publishing a small number of these articles does a great deal of good in making people think. Comins' article made a superb journey into the Galaxy that a "straight" piece could not have accomplished. — *Mark Mixon, Carbondale, Colorado*

WANTED: Eclipse Assistance

I'm a longtime amateur astronomer and am very interested in seeing the total eclipse this July, presumably in Baja California, Mexico. I've been studying astronomy since I was 10 years old and would like to have someone or some group help me with observing the 1991 eclipse. I've been looking forward to this event for many years and would be heartbroken if I couldn't see it. Therefore, I'm hoping that someone or some group of amateurs will answer my call by helping me out.

Transportation and lodging are the areas in which help would be needed. I'm 36 years old, deaf, and live with my parents. I can certainly share some of the expenses of travel and lodging but need someone to go along with to enjoy the eclipse safely. If anyone could help out, I would be most happy. — *Michael J. Hutchinson, 1121 Sumac Street, Longmont, Colorado 80501*

Look Out: Here Comes Vesta!

I greatly enjoyed your article on the Vesta occultation (January issue). I just had to write and tell you I was fortunate enough to witness the occultation of SAO 93228 by Vesta on January 3/4, 1991. Watching through my 6-inch reflector near Ajax, Ontario, I nervously waited as clouds rolled by off and on. As I watched through a hole in the clouds, at 0h29m31s UT the star suddenly disappeared. Then, 37 seconds later, the star brightened to its former appearance over a period of 1 or 2 seconds. Half an hour later I could see the star and Vesta clearly separated. Thanks to ASTRONOMY for providing an excellent article that allowed me to experience this memorable event! — *Frank Dempsey, Ajax, Ontario, Canada*

How Much is that Telescope in the Window?

I was struck by Rodger Gordon's letter about amateur astronomers and the high cost of telescopes (February issue). I agree with Rodger that today's amateurs would rather complain than go out and do the hard work it takes to get what they want. I don't even own a telescope, and the only binoculars I have access to have instructions written in some kind of pictographic language, but I still manage to observe quite a lot. Those amateur astronomers who are spoiled enough to own a telescope and are simply complaining that they need a bigger one have a real attitude problem. They ought to wake up, use some elbow grease, and start using their time for working another job, picking up aluminum cans, or doing piecemeal chores to earn the money. Instead, they appear to be simply whining. — *Cindy Cline, Winters, California*

When I first began reading ASTRONOMY about eighteen months ago I was intimidated by the ads that suggested you had to have "this or that kind of telescope" to be a serious amateur. It's normal to want the best things money can buy, but I think today's amateurs aren't inventive enough. Because I couldn't afford a telescope, I saved the change at the bottom of my pockets and designed and built my own 6-inch f/5 Dobsonian. Amateur astronomy isn't just for the rich — and the people who say it is are just not resourceful. — *Greg Heath, North Barrington, Illinois*

I've read with interest over the past months the ongoing discussion of telescopes and their cost. I have to admit that I am somewhat amused by it all. During the past year, after my three young children are tucked in, I've developed a passion for sneaking outdoors and identifying constellations, naming stars, and enjoying what little else I can see.

Maybe someday I'll have a big scope, but right now I'm perfectly happy with my $45, 10x50 binoculars. I suspect the diehard observers will cringe at that thought. But I remember the first time I saw the Andromeda Galaxy with the binoculars. It was a faint, gray smudge of light, but I ran inside screaming to my husband that I had seen deep space! How can you top that kind of excitement, even with a 40-inch telescope? — *Deborah Isaacson, Danbury, Connecticut*

Following Hubble's Troubles

Ron Cardinale's letter "Can't We Punish Them Some More?" (January Letters) is right on the money. I can't believe your distinguished magazine did not straightforwardly report news of the disastrous mistakes and coverup of the Hubble Space Telescope program. If Meade or Celestron had manufactured and sold to the general public instruments with serious defects, ASTRONOMY certainly would have scolded them and advised the public.

According to the *New York Times*, the prevailing news story now seems to be that Eastman Kodak was making the telescope's backup mirror and Perkin-Elmer feared that the Eastman mirror might be used if the P-E mirror wasn't finished first. So Perkin-Elmer rushed to finish the project and in the process made the tragic mistake.

It's shameful that Perkin-Elmer would act in such a way. They should be held fully accountable for the problems with HST. It's also shameful that ASTRONOMY chose to run NASA puff pieces and ignore the key facts of the investigation of the greatest flaw in the history of astronomy. How can this possibly serve the interests of the readers? — *Carl C. Yost, Newport Beach, California*

—NASA did share the blame for Hubble's defects because they accepted the finished article and approved Perkin-Elmer's fully documented test procedures.

Big Scopes German Style

In your otherwise excellent article "Optical Astronomy Looks to the Future" (November 1990 issue) you mentioned that the "largest of the new scopes and the earliest to receive first light is the 10-meter Keck telescope on Mauna Kea, Hawaii." Nowhere did you mention another large project, the 12-meter German Large Telescope. This project is being developed by the Ruhr University and the private company Krupp Industrietechnik. The project is currently being developed and we should be informed of a completion date in the near future. — *Emil Kirechiev, Esslingen, Germany* □

ASTRONOMY welcomes comments, suggestions, and additional information on articles and astronomy in general. Send your letters to: ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity.

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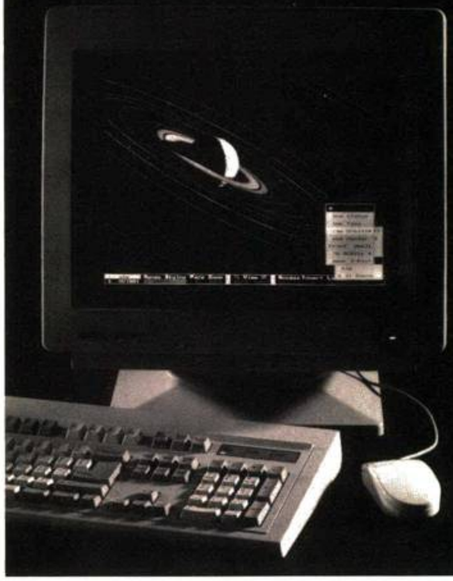

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The Klee.™ Not just another Barlow.

Designed by the master opticians who brought you the Pretoria, the 2.8X Klee has earned a reputation among experienced observers as the ultimate in image amplifiers. Only 2-1/4" long due to its unique 3 element air-spaced design. Multi-coated. **$75.00**.

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These are the excellent quality 80mm binoculars we have been selling for years updated with full multi-coating and BAK-4 prisms. Available in 11 or 20 power, they come complete with case, tripod adapter, and collimation certificate. If you are considering binoculars in this class, please give us a call and get the true story. **11X or 20X–$275 ea.**

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THE SELLING OF THE ECLIPSE, 1991

by R. S. Albright II

How much does it cost to view a solar eclipse?

If you thought the answer was "nothing," you're an idealist. Total solar eclipses are relatively rare and, more often than not, fall in the middle of the ocean or in some trackless waste on the other side of the planet. Hence, they are potentially expensive to view, unless one happens to fall where you live or within a reasonable driving distance.

That was my good fortune for the March 1970 solar eclipse, when my two college friends and I spent about $50 to $75 for a bare-bones trip to Dismal Swamp, Virginia. That price included 35mm film, transportation (gas for the old Rambler station wagon), accommodations (in the car by the side of the road), and meals (peanut butter sandwiches, crackers, Kool-Aid, and Screaming Yellow Zonkers). We had a fabulous time and I vowed that one day I would see another eclipse.

Costs have spiraled upward since then, our standards are now a little higher, and the next eclipse will not be as close to home. For my family of four, I have calculated the cost of viewing the July 11, 1991 solar eclipse from Hawaii for my family of four at $900 to $1900. I arrived at this range by comparing the cost of a seven-day Hawaiian eclipse vacation with the cost of the same trip any other week (in this case the week after the eclipse). The difference is the price of admission to the Sun and Moon's Cosmic Dance.

Will the expense be worth it? That all depends on individual circumstances. I first learned of the 1991 eclipse in early 1989. A vacation in Hawaii had long been a family goal, and the date of the eclipse happened to fall on my birthday, so this seemed like an ideal time to go.

In the spring of 1990, I began to consult travel agents about the event. The

HOW MUCH DOES IT COST?

	Eclipse Tour			Non-eclipse
	A[1]	B[2]	C[3]	Tour [4]
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# of Islands	1	1	2	2
Rental Car	Yes	No	No	Yes
Cancellation Insurance	No	No	No	Yes
Flexible[5]	No	No	No	Yes
Air Fare (round trip)	$1472	$1472	$1472	$1472
Tour Price	$4425	$5433	$5057	$3529
Total Cost	$5897	$6905	$6529	$5001
Cost Difference[6]	$896	$1904	$1528	——

[1] Terms: Deposit of 50% of tour price due at time of reservation (July 1989), with the balance due in January 1991 (6 months before departure).

[2] Cocktail party, buffet, two breakfasts, and Eclipse Seminar/Workshop are included in price. Terms: Deposit of $150 per person with reservation; balance due 90 days before departure.

[3] Accommodations on Maui. Guests will be flown from Maui to Kona, Hawaii, between 1:30 a.m. and 3:00 a.m. on July 11. Cost includes inter-island air fare and champagne breakfast following the eclipse, after which guests are flown back to Maui. Terms: Deposit of $100 per person with reservation; balance due 45 days before departure.

[4] Price is for three nights on Oahu, four nights on Maui, inter-island air fare, and transfers. Includes $140 cancellation insurance. Terms: Deposit of $100 per person with reservation; balance due 30 days before departure.

[5] Flexible refers to whether any deviations from the advertised itineraries were permitted. Tours "A" and "B" require a full seven-night stay at the hotel in Kona. In other words, to spend any time on any of the other islands would require either extending the vacation beyond seven days, flying to another island for the day and returning to Kona that night, or paying extra to stay somewhere else. Tour "C" includes two islands, but the time spent on the big island is limited to viewing the eclipse itself and the champagne breakfast afterward; there is no time for any sightseeing on Hawaii.

[6] Cost difference is the difference in total package price between the non-eclipse tour (one week after the eclipse) and each eclipse tour.

information I got was misleading. Even though I knew hotel rooms and travel arrangements would be booked early, I allowed myself to believe several travel agents who assured me that it was far too early to make arrangements, and that no tours would book dates until the 1991 prices were announced. (It should be noted that the travel agents I consulted were not specialists in astronomical tours.) I was told more than once to "check back in a few months."

I finally got in touch with a more experienced agent about the time Alan Dyer's article ("A Journey into Darkness") appeared in the July 1990 ASTRONOMY. Dyer told readers about "horror stories" involving airlines, hotels, and rental cars being sold out, but suggested that if readers booked a tour through a travel agent, space should still be available. When my agent did some checking, he discovered that available options were indeed very limited at that point, with nearly a year to go until the eclipse. Despite calling all his contacts in the Kona area, he was unable to book any hotel rooms directly. (The Kona area lies almost on the center line of totality, and that side of the "big island" has the most favorable and consistent weather at that time of the year.) As Dyer noted, tour companies had bought up all the hotel rooms in the area for that week.

My agent came up with three tours with available space, two of which had advertised in ASTRONOMY. (I ruled out cruises as a means of viewing the eclipse because of the cost and my family's desire to spend time in Hawaii.) The table at the bottom of page 14 summarizes the prices and terms of the three tours and compares them with a seven-day tour the following week. All of the tours in question included air fare from San Francisco. To this I have added the cost of air fare from my closest airport (Harrisburg, Pennsylvania) to San Francisco. All costs are based on a family of four (two adults and two children, ages 10 and 14).

I should point out that these tours are offered by companies that seem reputable. Nevertheless, from what I discovered, prices for accommodations have increased significantly for the week of the eclipse. This should not surprise anyone familiar with the market forces of supply and demand, as the number of hotel rooms in the Kona area is limited. Clearly the prices are relatively high, but they simply echo a hallmark of the free-enterprise system — supply and demand.

What I found more discouraging than the high prices was the inflexibility of all

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the eclipse tours. Although I have no doubt that the island of Hawaii by itself is a wonderful place to visit, we did not want to spend our entire stay there. After all, it was to be our first visit to the islands, and we wanted to visit a few sites on Oahu, such as Pearl Harbor. We also hoped to see Maui. Unfortunately, none of the eclipse tours permitted this sort of flexibility, unless we wished to extend our tour at a significant additional cost. In fact, the price difference between any of the eclipse tours and the non-eclipse tour we ultimately decided to book is actually greater than that shown, since the non-eclipse tour includes so much more.

If you are trying to combine witnessing a cosmic event with a reasonably priced family vacation, you could well be disappointed. But if you are looking for a chance to view one of the most spectacular of all celestial events and do a little sightseeing on the side, any of these tours could be for you. How much does it cost to view a solar eclipse? Unfortunately, for the best eclipse for North American viewers in the foreseeable future, the cost will be high. But what person who has ever seen a solar eclipse can say that basking in seven minutes of totality isn't worth the price?

A BUNCH OF HAPPY (ASTRONOMY) CAMPERS

by Chris Sinclair

Advanced Astronomy Camp — Wow! What an opportunity. From the moment I heard about the University of Arizona's camp for young astronomers, I was excited. The first thing I did was write the university for more information about the camp. I eagerly leafed through the packet of goodies when it arrived and discovered, much to my dismay, that I would have to write an essay to get in. Disappointed by this news, I threw the packet into my room — a good alternative to the trash because I wouldn't have to drag it to the curb — and tried to forget about it.

But it didn't work. "Hold it!," I said to myself. "Just write the essay and maybe you'll be accepted!" So I looked at the essay choices and decided to write on "life in an hypothetical binary star system." One week and three trips to the library later, a very excited Chris Sinclair received acceptance into the camp.

The months between March and June of last year flew by, and before I knew it I was getting off a plane at the Tucson airport (carrying a backpack loaded with astronomy books and a roll of film that cost a small fortune at the Dallas-Fort Worth airport). Joan Morrill, the camp coordinator, flagged me down, and then we were off to the U of A campus. After meeting the other 11 campers, we were off again, this time to the top of Mt. Lemmon where we would spend the week. That night we had a picnic and met our counselors — Don, Davy, Kim, and Todd. Kim made us play some really confusing game to help us learn each others' names. With that accomplished, we were taken to "meet the 60-inch telescope," one of three telescopes we had access to for the week. At about midnight we retired into the astronomers' dorms, tired from the long day.

Morning came early, and we prepared for a day of lectures. We dreaded the lectures at the beginning of the week, but by week's end we actually looked forward to them. Various professors and graduate students (including our counselors), spoke on some of the "hot topics" in astronomy — galaxy redshifts, the cosmic background radiation, the missing mass problem, and more. In addition to these topics, we also learned about such fundamental astronomical concepts as stellar evolution, stellar spectral features, and celestial mechanics. We learned the "science" of astronomy during the day, which prepared us for observing at night.

But the sheer beauty of the pristine mountain sky almost made us forget our daytime learning. Only one thing was better than being under the serene skies and that was being under the serene skies with BIG telescopes! Our three observing teams — the Scorpions, the Dolphins, and the Eagles — alternated between the 60-inch telescope, the 40-inch telescope, and the 16-inch Schmidt camera. My group (the Scorpions) went to the Schmidt first. There we took pictures of NGC 4565, NGC 4559, M101, and RR Lyrae. Although our pictures looked good on the original 5° negatives, minute guiding errors meant that they didn't enlarge well. One of the other teams, however, got some beautiful photos of the North America Nebula and Comet Levy.

At the 60-inch telescope, where our team spent the next night and two nights later in the week, we took exposures of several globular clusters for a research project, as well as spectra of various stars and nebulae.

We used the 40-inch scope to get a light curve of the variable star RR Lyrae. We took both photometric and photographic data to get enough information for this project. I was also able to take photographs of galaxies in Andromeda and Pegasus while the other campers were asleep under the stars. Of all the opportunities the camp offered, the observing was far and away my favorite.

After collecting all the information at the telescopes, we analyzed the data and prepared a short synopsis of the project results. In my group, Mike and I analyzed the globular cluster data and made a graph of the distances to the globulars. We assumed that all the globulars were the same size and luminosity, which (although not true) was close enough for our purposes. Other teams also worked on this project, and it was interesting to compare the results among the teams. Other projects displayed were the light curve of RR Lyrae and the use of a sextant to measure the circumference of Earth. Doing research based on our own observations gave us some real insight into the world of professional astronomy.

In addition to the work on Mt. Lemmon, we also took field trips to the University of Arizona Mirror Lab and to Mt. Hopkins. At the Mirror Lab, we saw a video of spin casting and then saw a mirror blank on which the technique was used. At Mount Hopkins we got to see the Multiple Mirror Telescope, whose six mirrors combine to make it the third-largest optical telescope in the world. The telescope was truly impressive, even though we didn't get a chance to look through it! We all felt that the 6-hour trip to see the Mirror Lab and the MMT was worth it.

Sadly, all good things must come to an end, and the astronomy camp was no exception. The last official part of camp was a graduation ceremony. The counselors presented several humorous (and often embarrassing) awards, apparently in an attempt to get back at us for keeping them up at night. But there were also serious awards — Most Promising Young Astronomer (male and female), Best Essay, Most Inquisitive, and Most Determined, among others.

The hard part came after all the awards were given out and everyone received diplomas — it was time to leave. Many of the campers promised to keep in touch, and there were more than a few teary eyes. As my new-found friends and I boarded planes heading in a dozen different directions, I'm sure we all shared the same thoughts about the incredible experiences we had at camp. It's a week in our lives that we'll remember for a long, long time. □

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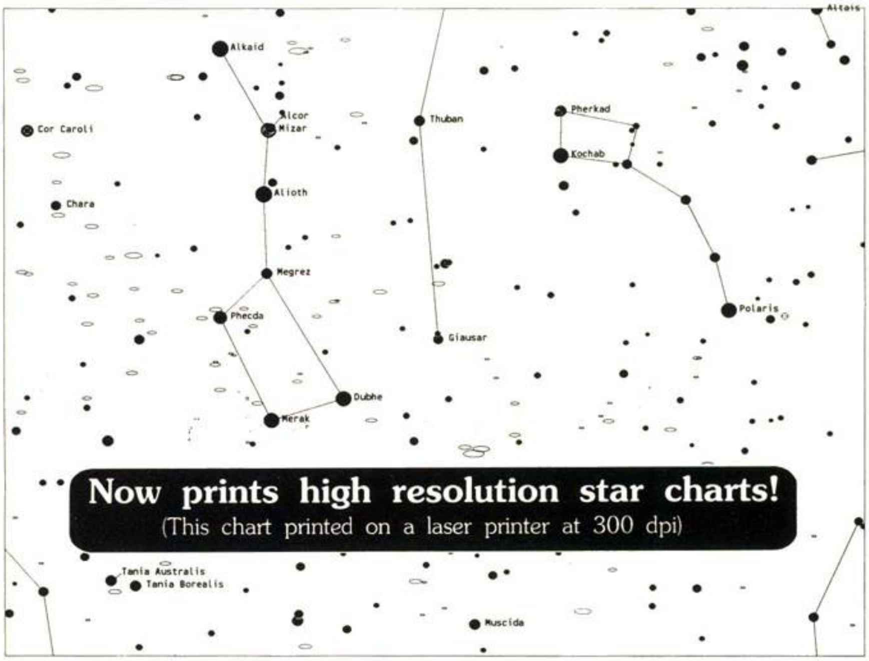

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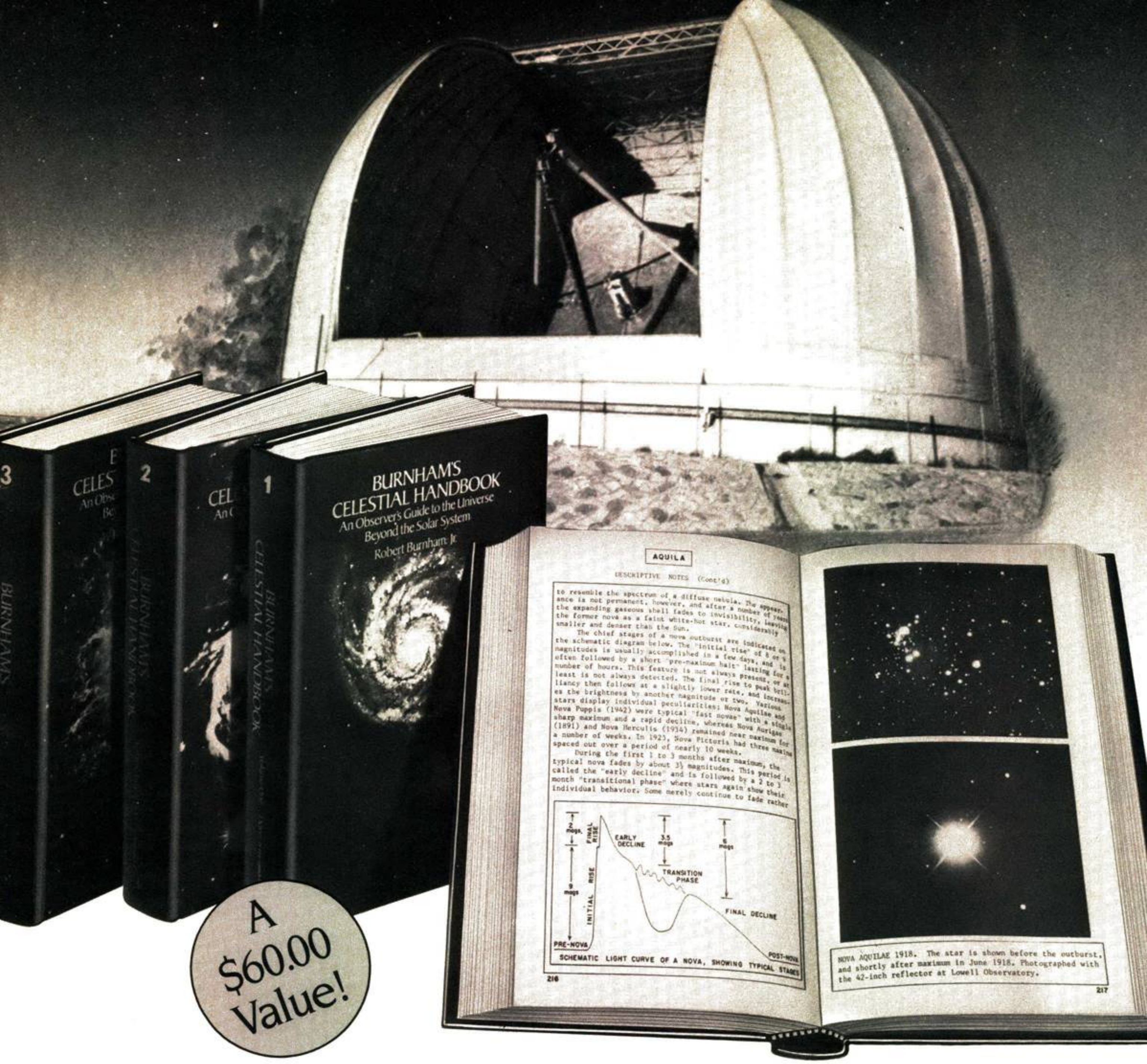

AQUILA

DESCRIPTIVE NOTES (Cont'd)

to resemble the spectrum of a diffuse nebula. The appearance is not permanent, however, and after a number of years the expanding gaseous shell fades to invisibility, leaving the former nova as a faint white-hot star, considerably smaller and denser than the Sun.

The chief stages of a nova outburst are indicated on the schematic diagram below. The "initial rise" of 8 or 9 magnitudes is usually accomplished in a few days, and is often followed by a short "pre-maximum halt" lasting for a number of hours. This feature is not always present, or at least is not always detected. The final rise to peak brilliancy then follows at a slightly lower rate, and increases the brightness by another magnitude or two. Various stars display individual peculiarities: Nova Aquilae and Nova Puppis (1942) were typical "fast novae" with a single sharp maximum and a rapid decline, whereas Nova Aurigae (1891) and Nova Herculis (1934) remained near maximum for a number of weeks. In 1925, Nova Pictoris had three maxima spaced out over a period of nearly 10 weeks.

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SCHEMATIC LIGHT CURVE OF A NOVA, SHOWING TYPICAL STAGES

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NOVA AQUILAE 1918. The star is shown before the outburst, and shortly after maximum in June 1918. Photographed with the 42-inch reflector at Lowell Observatory.

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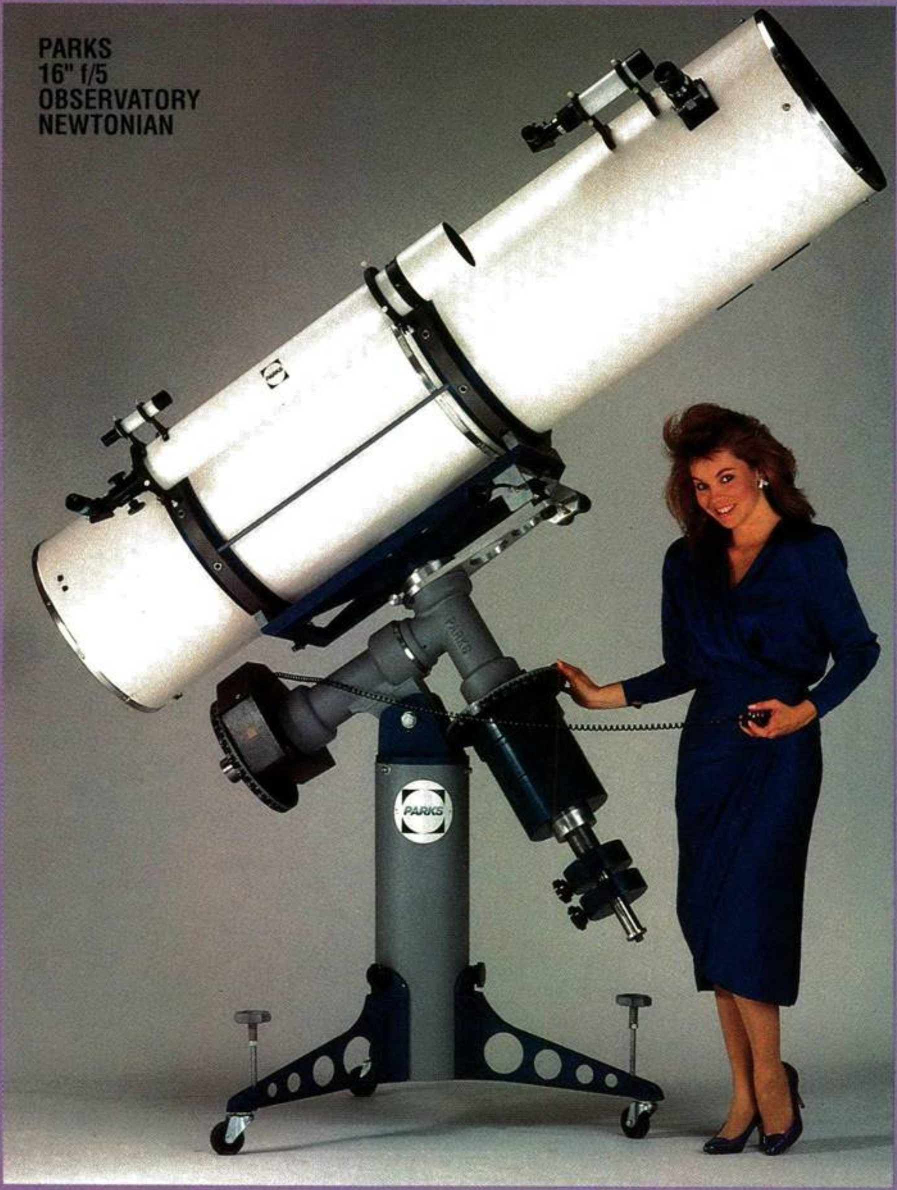

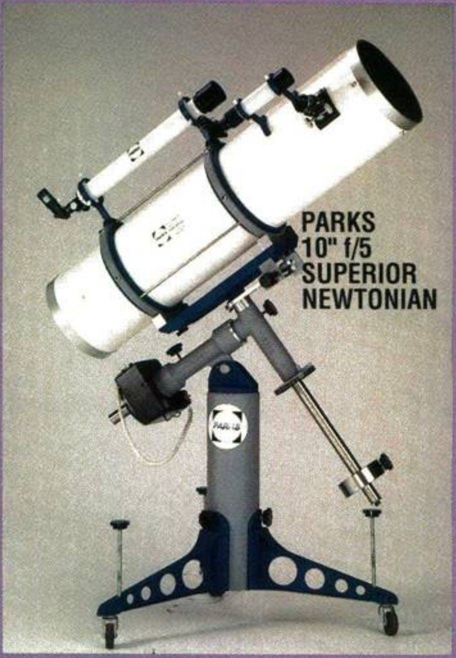

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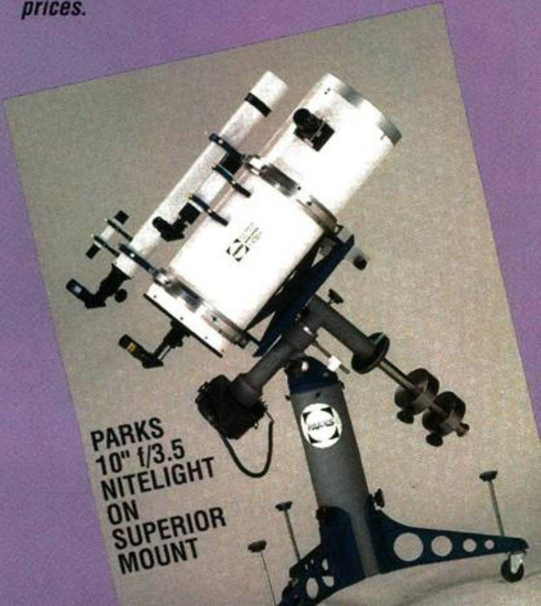

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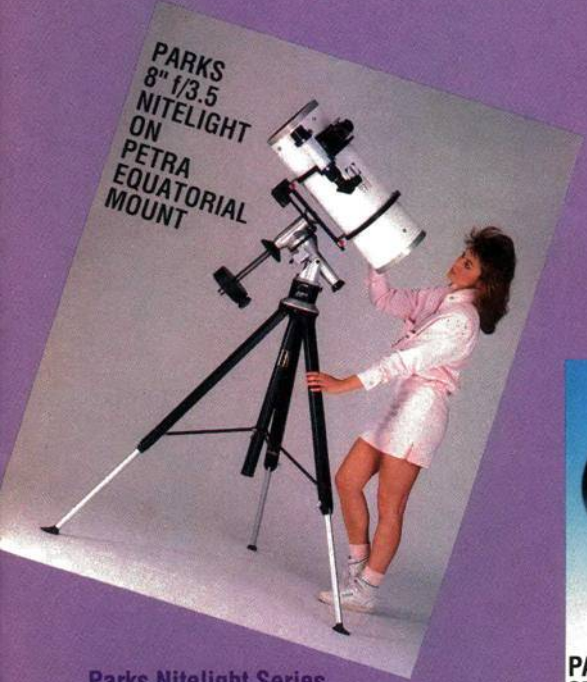

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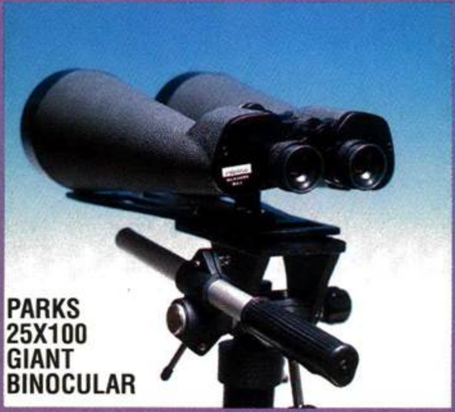

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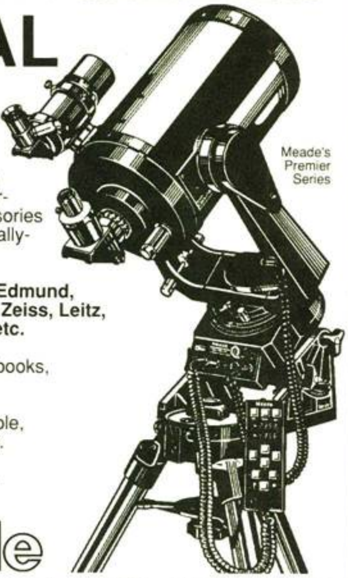

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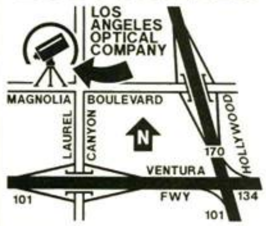

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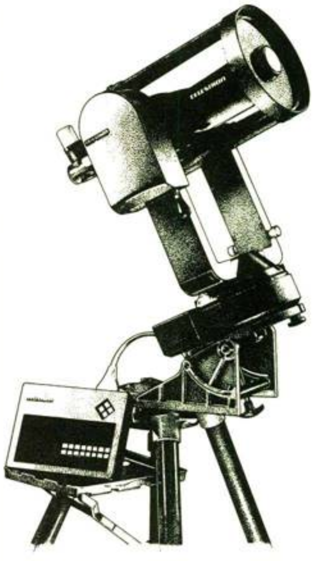

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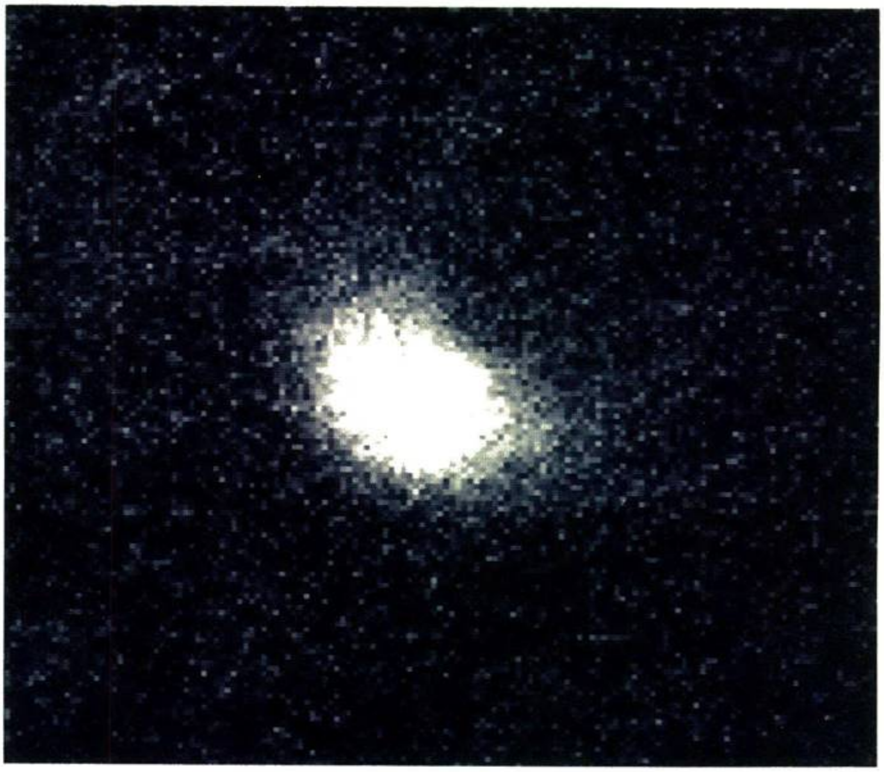
A DRAMATIC OUTBURST FROM COMET HALLEY

When we last left Comet Halley, it was a faint point of light moving slowly through the outer solar system, a mere ghost of the bright comet that streaked past Earth some five years ago. But the supposedly quiescent comet stunned astronomers in February when a huge eruption made it appear more than a thousand times brighter than it had been.

Belgian astronomers Olivier Hainaut and Alain Smette discovered the outburst on February 12 while observing Halley with the Danish 1.54-meter telescope at the European Southern Observatory in La Silla, Chile. They had expected Halley to look much as it had in 1990 — a pinpoint nucleus with no surrounding coma of gas or dust. What they found instead was a nebulous object shining at 19th magnitude, some six magnitudes brighter than astronomers expected Halley to be. Further observations showed that the nebulosity was due to a huge cloud of dust that had erupted from the comet's nucleus.

The biggest question concerning the discovery is how such an eruption could occur so far from the Sun. Halley is now 14.3 astronomical units (over 1.3 billion miles) from the Sun, about halfway between the orbits of Saturn and Uranus. At this distance the surface of the nucleus has a temperature of about –200° Celsius (–330° F or 73 kelvins), so cold that the water ice that makes up the bulk of the comet must be frozen solid. Until Halley's outburst, no one had ever seen a comet erupt at such a large solar distance or such a low temperature.



A HUGE ERUPTION on Comet Halley has made it a thousand times brighter than it should be, raising questions as to how it could become active when it is so far from the Sun. European Southern Observatory photo.

Astronomers have looked at several possible explanations for the outburst. The most likely seems to be that some substance like frozen carbon monoxide, which can vaporize at the comet's temperature, is still active. If a pocket of frozen carbon monoxide just under the comet's surface were to vaporize slowly, the pressure could build up until the gas burst through the crust and released the huge dust cloud.

Another possible explanation is that Halley collided with a small, previously unknown object, heating the surface ices and triggering the release of the dust. Because Halley is only about 15 kilometers long by 6 kilometers wide, however, the chance of such a collision taking place is remote. A third scenario is that highly energetic particles in the solar wind heated the comet's surface. Once again, however, most astronomers doubt that this could happen at such a large distance from the Sun.

For now, observational astronomers are continuing to monitor the behavior of Halley to see if the comet has any more tricks up its sleeve. And theoretical astronomers are beginning to rethink their models of cometary nuclei and how the nuclei interact with the Sun. The huge eruption will change the way we think about comets, and ensures Comet Halley's reputation as the most famous comet of all.

HAS THE 'DINOSAUR' IMPACT SITE BEEN FOUND AT LAST?

A crater 120 miles across lies buried 3,000 feet deep near the northern coast of Mexico's Yucatan peninsula. It could be the crater left by the asteroid impact that many scientists think wiped out much of Earth's life, including the dinosaurs, 65 million years ago.

Glen Penfield, a Houston geophysicist, identified the buried crater from geophysical studies made for PEMEX, the Mexican national oil company, in 1978. Confidentiality agreements prevented Penfield from publishing his data at the time. Recently, however, the information became public knowledge when core samples from oil wells drilled in the area were found at a depository in New Orleans.

Penfield said the cores contain quartz that has been shocked as could be expected from exposure to sudden high temperatures and pressures. Additional evidence supporting this crater as "the" site of the impact comes from other core samples and a geological discovery made along the Brazos River in Texas a few years ago.

A core sample from a well drilled about 30 miles off the edge of the Yucatan crater contains a 250-foot-thick layer of pulverized rock. Much of this is shocked quartz that could have been deposited by the impact that created

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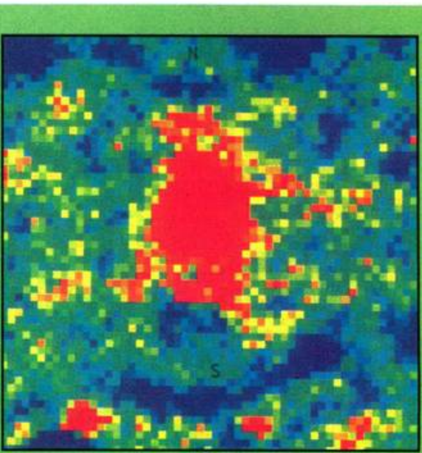
the crater, according to Alan Hildebrand of the University of Arizona. Hildebrand worked with Penfield to identify the crater and reported their findings to the American Geophysical Union.

A crater in the Yucatan also fits well with evidence of a tidal wave (or tsunami) in what is now Texas — across the Gulf of Mexico from the crater. Such a tidal wave could have been the result of an asteroid impact into or near the shore of the Gulf. (See "The Day the Earth Caught Fire," AstroNews, December 1988.)

The crater is centered near Chicxulub (pronounced CHEEK-shoe-lube), a small town in northern Yucatan. Hildebrand finds the name, which means "devil" in the local Maya language, highly appropriate for the crater.

Calculations show that an explosion powerful enough to blast a 120-mile-wide crater would release as much energy as 200 million atomic bombs the size of that which destroyed Hiroshima. Although there is much debate about the details of the impact's aftermath, many scientists believe that dust and soot from fires would be thrown high into the atmosphere where they would severely diminish the amount of sunlight reaching Earth's surface for several years. — *Ray Grasshoff*



GRAVITY HELPS ASTRONOMERS probe a galaxy 6 billion light-years away. In this digital image taken with the 4.2-meter William Herschel Telescope in the Canary Islands, the two faint arcs above and below the central galaxy are actually the warped images of a much more remote galaxy. The nearby galaxy is acting like a lens — its gravity magnifies and distorts the light from the galaxy that lies behind it, a process that makes it possible for astronomers to see galaxies that would otherwise be too faint. In this case, astronomers at the University of Durham in Great Britain have obtained spectra of the lensed arcs and have determined they belong to a spiral galaxy undergoing an intense burst of star formation. Image courtesy Richard Ellis, Jeremy Allington-Smith, and Ian Smail, University of Durham.

MT. GRAHAM TELESCOPES WILL NOT DISTURB THE SQUIRRELS

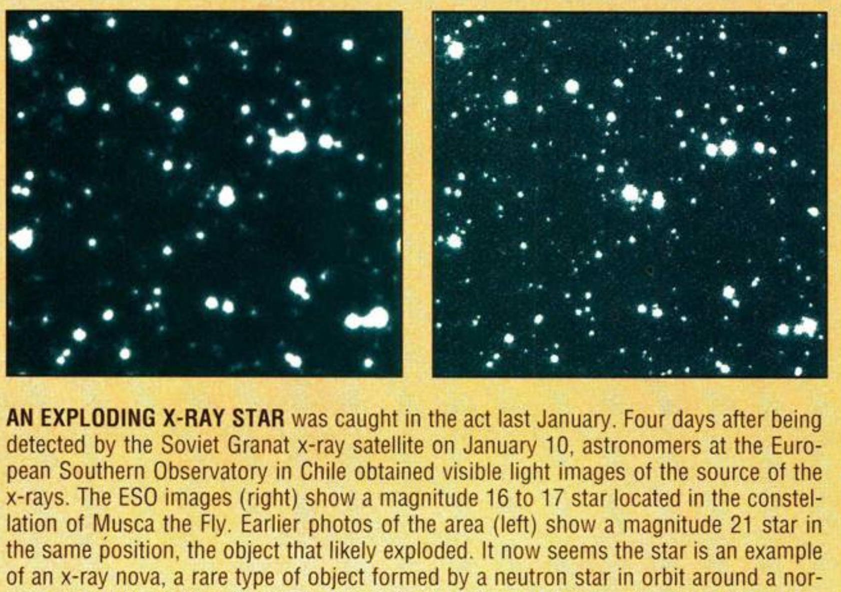
The observatory atop Mt. Graham in southeastern Arizona will not affect the red squirrels that live on and around the mountain's summit. That is the conclusion of a recently issued U. S. Forest Service study of the animals' habitat conducted during the summer of 1990.

The observatory was the focus of a heated controversy between the University of Arizona and an ad hoc coalition of local environmental groups. The latter sought to stop the project on the grounds that it was endangering a subspecies of red squirrel living on the mountain.

The controversy revolved around how large an area the squirrels needed to maintain a viable population and how much of an impact the observatory would have on that area. (The observatory, now under construction, will have three telescopes and will occupy 8.6 acres when finished. If all seven of the planned telescopes are built, a total of 24 acres would be occupied.)

In the new study, biologists surveyed a much larger area of the mountain than had been included in previous surveys. The new work confirmed the earlier population estimate (450 to 500 squirrels), but found that instead of being confined to a specific type of spruce forest at or above 10,000 feet, the squirrels actually roamed over a zone of mixed conifers that lies between 9,000 and 10,000 feet.

The report concluded that Mt. Graham contains 11,000 acres of habitat for the squirrels, and that more than 60 percent of the squirrels live outside the 1,700-acre reserve which includes the area of the observatory.



AN EXPLODING X-RAY STAR was caught in the act last January. Four days after being detected by the Soviet Granat x-ray satellite on January 10, astronomers at the European Southern Observatory in Chile obtained visible light images of the source of the x-rays. The ESO images (right) show a magnitude 16 to 17 star located in the constellation of Musca the Fly. Earlier photos of the area (left) show a magnitude 21 star in the same position, the object that likely exploded. It now seems the star is an example of an x-ray nova, a rare type of object formed by a neutron star in orbit around a normal star. Matter falling onto the neutron star's surface explodes, releasing a burst of x-rays and visible light. Only four other x-ray novae have been detected since 1975. Nova Muscae 1991 is unusual because it was seen so early in the explosion process in both the x-ray and visible bands. Photos courtesy European Southern Observatory.

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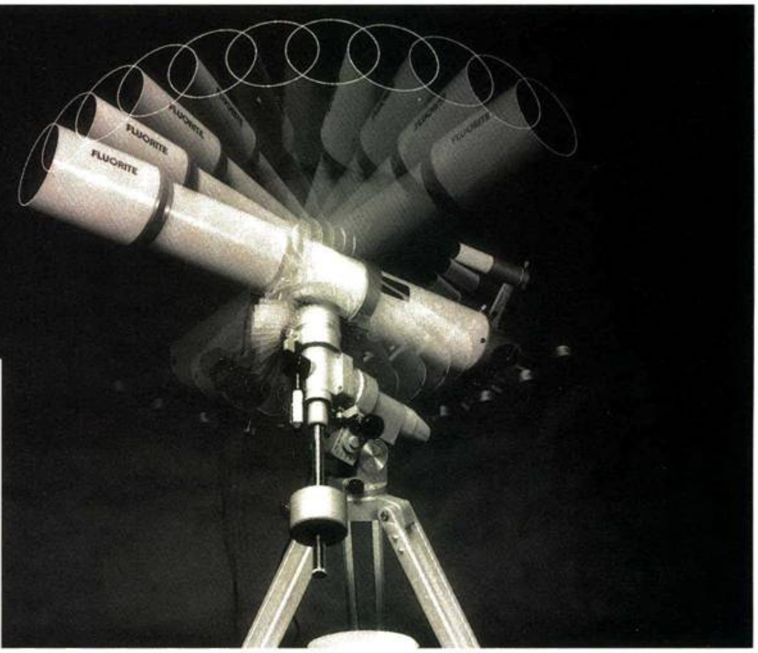

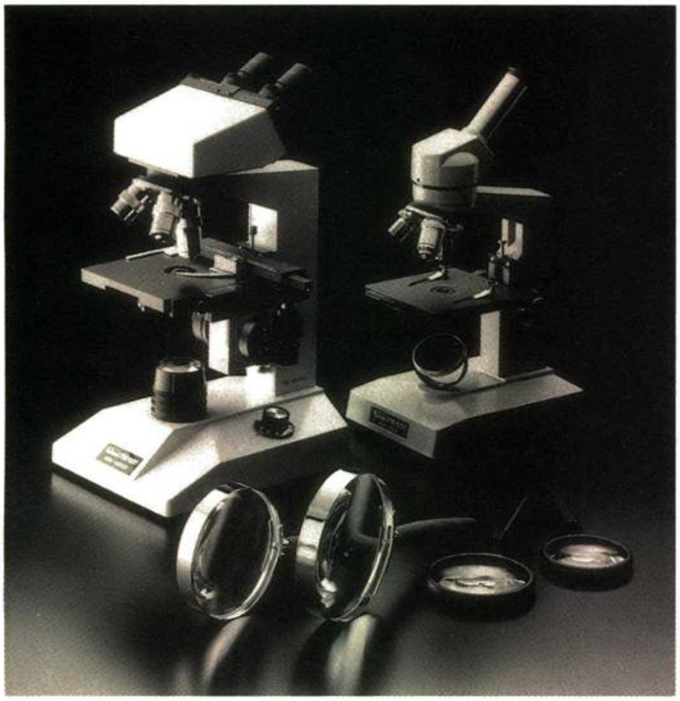

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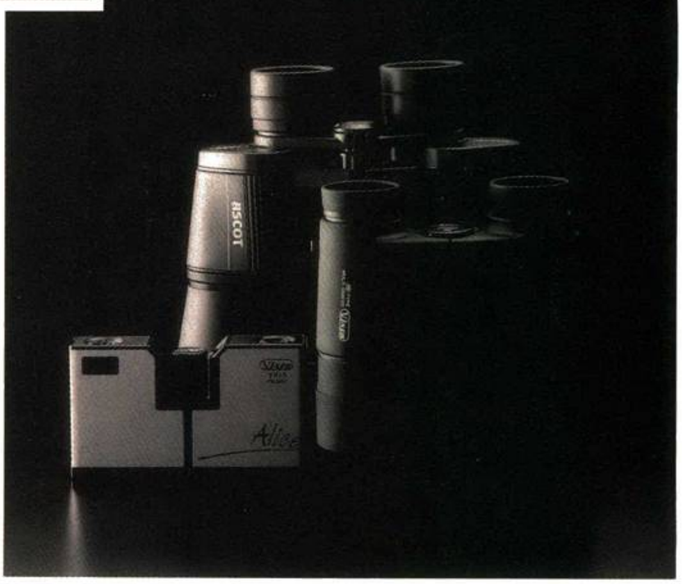

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ASTRONOMERS FLOCK TO KEYS FOR WSP

Five hundred and twenty enthusiastic amateur astronomers enjoyed southern hospitality at the 1990 Winter Star Party, held in the Florida Keys. Although unseasonably cool temperatures drove observers to sweaters and parkas against a 50-degree (Fahrenheit) chill, the sky cleared for a glorious all-night observing party.

The annual four-day event, sponsored by Miami's Southern Cross Astronomical Society, ran from Thursday, February 14, to Sunday, February 17.

Back by popular demand was Southern Cross Astronomical Society vice-president Tippy D'Auria, with his presentation on the scale of the solar system. Using rolls of toilet tissue to illustrate distance (at a scale of one square of paper to one million miles), D'Auria spooled off nearly four rolls of Scot tissues (1000 sheets, or one billion miles to the roll) to reach the planet Pluto. The audience, wreathed in tissue, cheered and clapped for each new planet.

Observer and *Sky and Telescope* writer Steve O'Meara described his discovery of a new feature on Mars. International Dark-Sky Association president Tim Hunter, and *Touring the Universe through Binoculars* author Philip Harrington, drew attentive audiences during the Friday afternoon program.

The Saturday program highlighted talks by ASTRONOMY Editor-in-Chief Richard Berry, speaking on digital "astrophotography" and by Abrams Planetarium director Robert Victor who spoke about the quest for young moons and planetary conjunctions. Donald Parker, ALPO Mars section recorder, told an eager audience why it's important (and fun) to observe the Red Planet, and comet-hunter David Levy (who had just discovered his eleventh comet) reviewed Comet Halley and the several comets named Comet Levy.

During the day, star-party attendees looked over telescopes, talked with each other, or went to nearby beaches and state parks. In the evening, however, attention turned to observing. Besides dozens of 6-inch refractors and 8, 10, 12.5, and 16-inch reflectors, half-a-dozen 20-inchers as well as a 25-inch and a 30-inch Dobsonian provided massive observing power. Because of the large number of telescopes, viewing lines were only five or six people long, and waiting times were short. Jupiter, Comet Levy, the Horsehead Nebula, and Eta Carinae were among the top observing attractions.

On Saturday night a barium cloud provided an unusual sight. The barium cloud, released by CRRES research satellite, appeared as a 4-degree long by $^1/_4$-degree wide streak on the meridian around midnight. Over the course of an hour, it gradually faded away.

Next year's Winter Star Party is scheduled for January 28 to February 2.

SUNSHINE, PALM TREES, and CLEAR SKIES make the Winter Star Party a treat for observers from chilly northern states. Photo by Richard Berry.

ADLER'S GRAND REOPENING

The first modern planetarium in the Western Hemisphere completed a significant transformation on March 2, 1991. On that day Chicago's Adler Planetarium held a grand reopening at which the public first saw an extensively refurbished planetarium and museum. The rebuilding of Adler is "the result of systematic planning and forward thinking on the part of our staff and board of trustees, fueled by a tremendous show of financial support from our contributors," says director Joseph M. Chamberlain.

Adler's improved facilities include a revamped Sky Show theater that uses a Zeiss Mark VI projector, 150 slide projectors, helium/neon and argon lasers, a Sony video projection system for planetarium shows, as well as an improved Universe theater for multimedia shows. Each seats an audience of 430. Additionally, the two theaters are now connected by a "stairway to the stars," a 77-foot escalator fitted with fiber optics simulating the night sky. After seeing a show in the Universe theater, audience members now travel directly into the Sky Show theater by means of the specially built ramp. "As far as we know, it's the longest escalator in Chicago," says Chamberlain.

Improvements that are not so readily apparent include substantially expanded underground office space, improvements in the visitors' food service, and funds for an increased effort in education and a teachers' workshop program. Altogether, more than twenty major donors gave Adler $7.1 million to complete the refurbishment. Perhaps most exciting for the Adler staff is the ability to create more vivid, active graphics for shows. "Our special effects now have a much more fluid, lifelike look," says James Sweitzer, Adler's assistant director. According to Mark Paternostro, the observatory's principal artist, "with our new screening room, front projection techniques, and computer animation, we're in a position to create the most exciting shows in the world."

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ANNOUNCEMENT — The Phoenix Youth Astronomical Network (PYAN) is looking for teenage members in the Greater Phoenix area. Contact John Barentine, c/o PYAN, 3744 W. Brown, Phoenix, AZ 85051.

FOR SALE — ASTRONOMY, November 1981 - January 1990 (missing May 1982 and November 1985). Also assorted issues of *Sky & Telescope* from 1984-present. Contact Ted Wiatrak (with offers), Box 152, Loyalhanna, PA 15661. Phone (412) 539-8481.

FREE — Five-year collection of NASA 2-line orbital elements from November '84 to November '89. You pick up (700 lbs). Contact Steve Wood, PO Box 592175, Orlando, FL 32859. Phone (407) 240-8121.

WANTED — Brazilian seventeen-year-old seeks correspondence with other teens and people across the universe. Will respond to all letters in English, Italian, German, French, Spanish, or Portuguese. Contact Harley Rodrigues Soares, Rua Burakama, 257, Capitao Eneas-M.G.-Brasil 39445.

WANTED — Twenty-three-year-old beginner in astronomy seeks correspondence with anyone interested in astronomy or any other science. Will reply promptly. Contact Rick Donovan, 100 E. Glenolden Ave, Apt K-6, Glenolden, PA 19036.

FOR SALE — Meade 40mm Plössl, $67. Celestron star diagonal, $27. *Sky Atlas 2000,* $16. All mint, all postpaid. Will donate table tripod to astronomy club. Send SASE for essay on origins. Contact Rodric Ness, 5580 Whispering Oak Way, Paso Robles, CA 93446. Phone (805) 238-7068.

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FOR SALE — Two-year-old Meade 10" 2120 LX5 with dec. motor, dew shield, counter weights, and more. Superb condition, $1,795. Odyssey 13.1" Dobsonian, $300. Contact Mark Stephenson, 2434 Spicer Road, Beavercreek, OH 45431. Phone (513) 426-0513.

WANTED — To everyone in Portugal, who would like to form a club of astronomy, contact Carlos Maudslay-Rua daPalmeira 418-4400 U.N. GAIA. To exchange correspondence with any amateur from anywhere. Write in English, French, or Portuguese.

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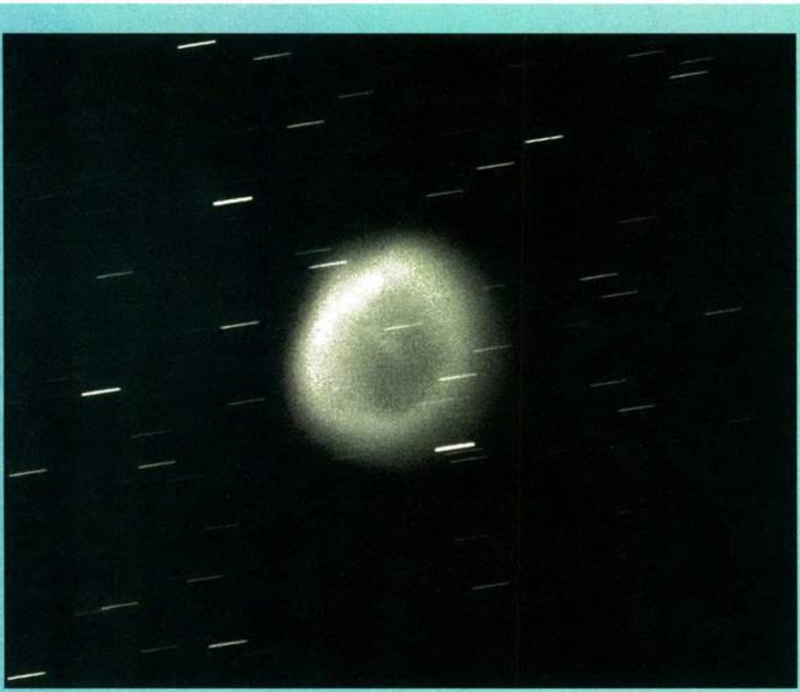
IS NEPTUNE USING SUNBLOCK?

Neptune is just as bright as it was five years ago, and that's news.

In a report published in the February 14 issue of *Nature*, Lowell Observatory astronomers Wesley Lockwood and Don Thompson announce that Neptune did *not* dim as solar activity increased in the present sunspot cycle, which appears to have reached its maximum in 1990. This finding comes as a surprise because since 1972, when Lockwood and Thompson's precise measurements began, Neptune has darkened as the Sun's activity increases and brightened as solar activity wanes. The brightness changes amount to only 0.05 magnitude, but lie well above the error limit.

Planetary scientists have proposed various theories to account for the changes. Most unusual among these is that Neptune "tans" as increasing amounts of ultraviolet light from the Sun darken the hydrocarbon particles in the planet's stratosphere (see AstroNews, February 1990).

So why did Neptune maintain the high reflectivity characteristic of solar minimum into the period of high solar activity — and, moreover, one of the most active solar maxima on record? Lockwood and Thompson do not know but speculate that perhaps the normal cycle has been interrupted by some passing atmospheric event like the Great White Spot seen on Saturn last autumn. But for now, they say, "only time and further observations" will show what is happening.



GLOWING LIGHTS IN THE SKY were created last January by NASA's Combined Release and Radiation Effects Satellite (CRRES). On several occasions CRRES injected lithium and barium into Earth's magnetosphere. The glowing chemicals acted as tracers of Earth's magnetic field lines. The NASA photo above taken from Lincoln, Massachusetts, by Patti Wheaton shows the orange lithium cloud release of January 17. The photo at left by Gregory Gage of Pomfret, Maryland, shows the purple streak from the January 16 barium cloud release.

NAMING THE NAMES OF VENUS

Radar surveys by the Magellan spacecraft are adding thousands of features to the map of Venus — and the Magellan project and the U. S. Geological Survey are looking for help from the public in naming them. The Geological Survey says that about 4,000 names for Venusian features are going to be needed in the coming decade.

Names proposed by the general public should be sent to the Magellan offices at the Jet Propulsion Laboratory where they will be compiled and given to the committee that devises names for features on planetary bodies. This committee works under the auspices of the International Astronomical Union, which gives final approval to all names chosen.

By international agreement, all Venusian features are named for women — real, fictional, or mythological. (Three exceptions exist, dating from before the convention was adopted: Maxwell Montes, named for the early radar pioneer James Clerk Maxwell, and Alpha and Beta Regio.)

The women chosen must be dead for at least three years. Names of military and political figures from the 19th and 20th centuries are specifically forbidden, as are the names of persons prominent in any of the major world religions. Names submitted should be accompanied by a one or two sentence rationale for the honor, together with a reference book citation, if possible.

Send proposed names to Venus Names, Magellan Project Office, Mail Stop 230-201, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109. □

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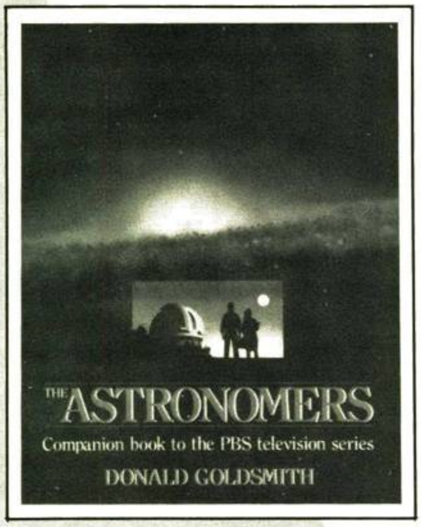

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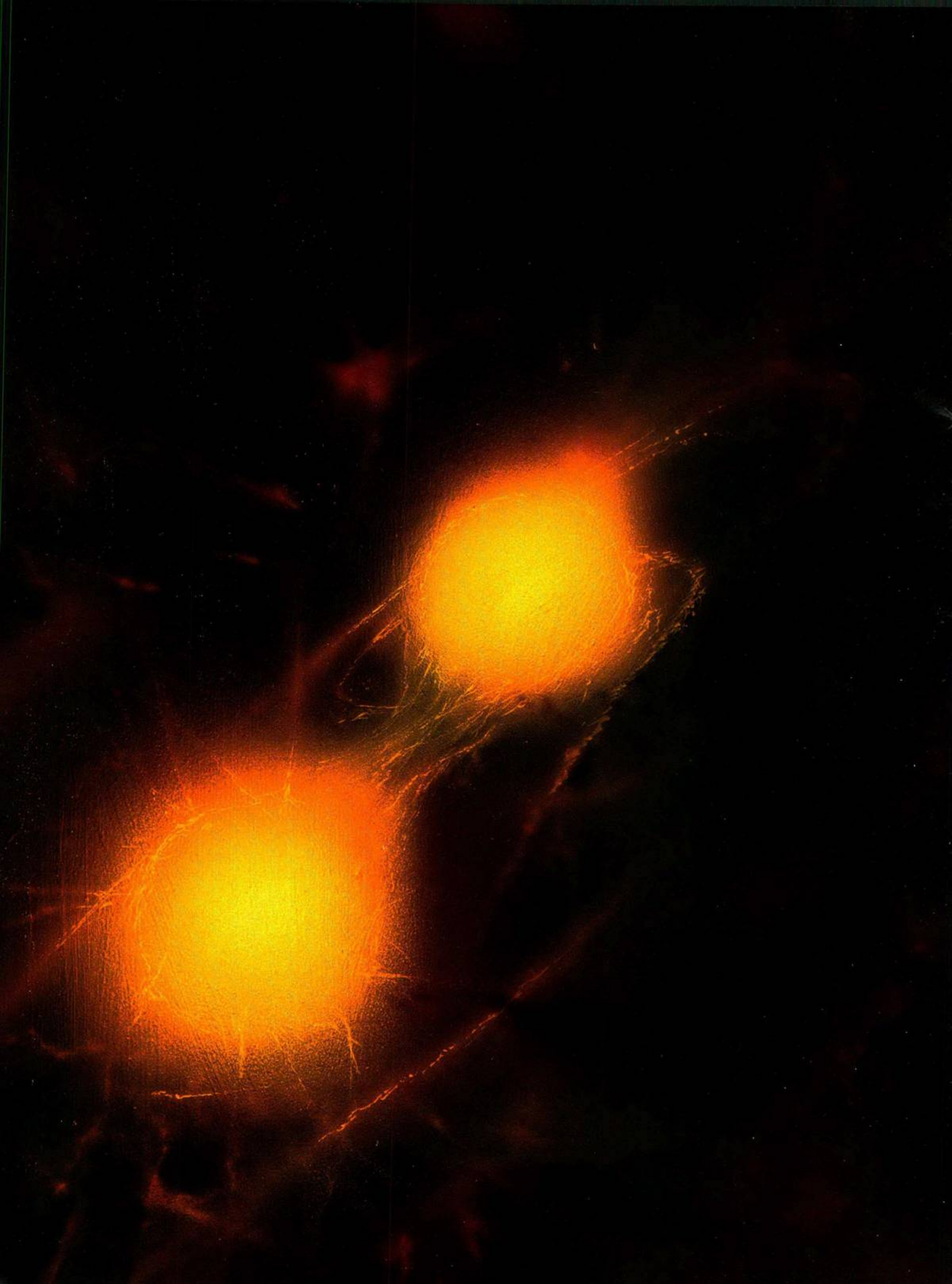
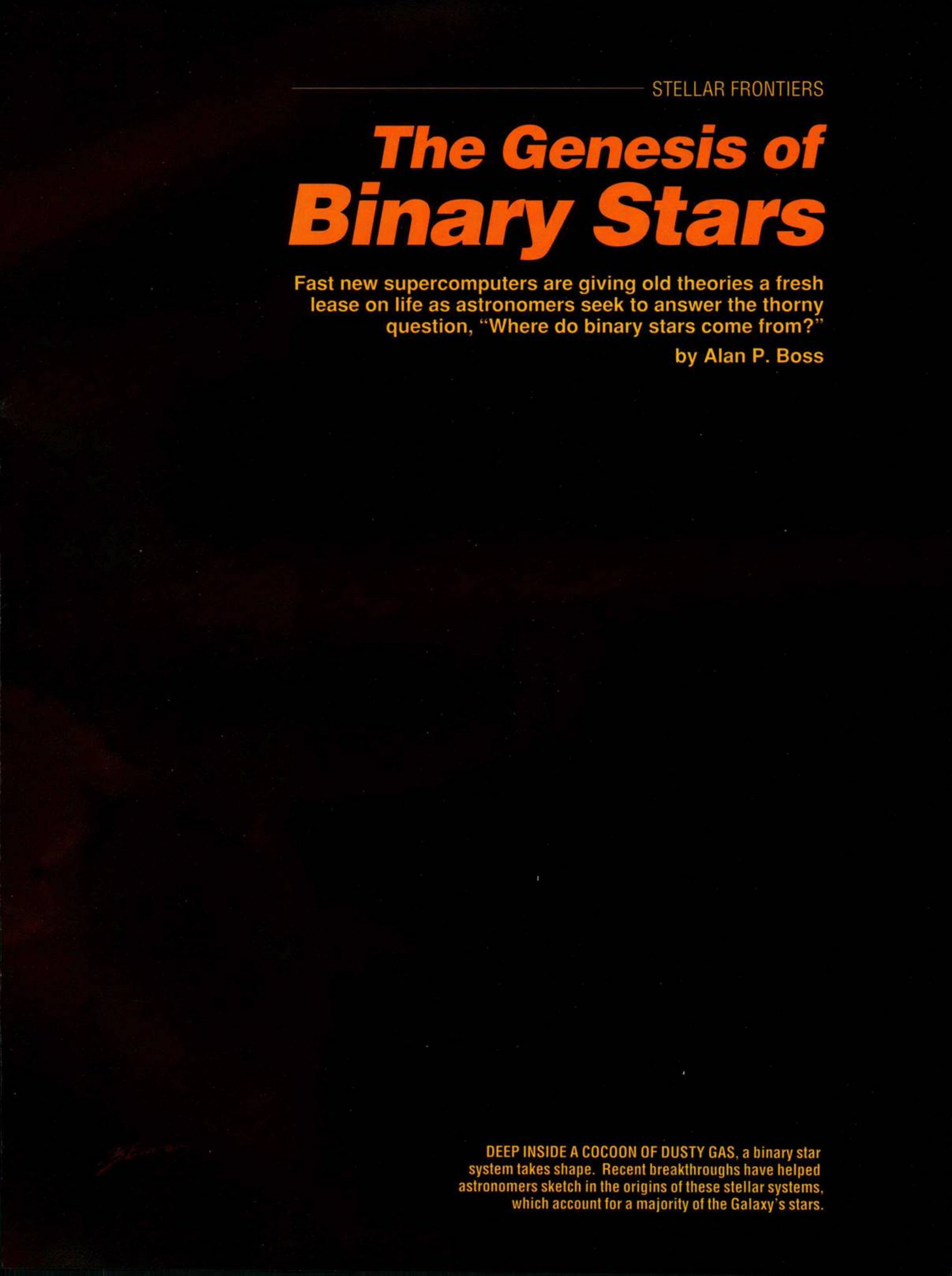


STELLAR FRONTIERS

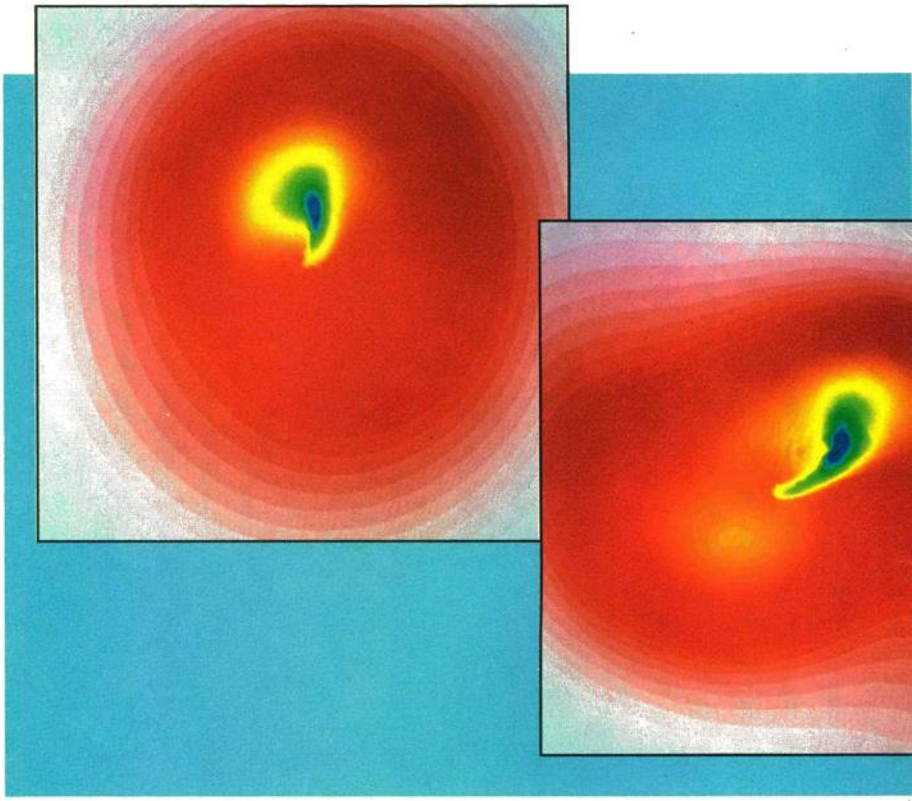
The Genesis of Binary Stars

Fast new supercomputers are giving old theories a fresh lease on life as astronomers seek to answer the thorny question, "Where do binary stars come from?"

by Alan P. Boss



DEEP INSIDE A COCOON OF DUSTY GAS, a binary star system takes shape. Recent breakthroughs have helped astronomers sketch in the origins of these stellar systems, which account for a majority of the Galaxy's stars.



Some suns are born solitary, with no stellar siblings. Others, like the beautiful blue and gold Albireo that arches overhead tonight in the beak of Cygnus, form in twos or threes or more.

These double and multiple stars have long offered pretty sights to backyard observers, but they have been a tremendous headache to generations of astronomers. It is only in the last decade that astron-omers have made real progress in understanding how these star systems form, and this has come about mainly through the marriage of sophisticated theory to fast super-computers.

For a long time after the telescope was invented, no astronomer knew that double stars even existed. Observers simply assumed that whenever they saw two stars close together in the eyepiece it was just a chance alignment of objects at different distances from Earth.

The discovery of true binary stars — two stars actually locked in a gravitational embrace — came out of the research of William and Caroline Herschel, a brother and sister "binary" who might well be the patron saints of backyard astronomy.

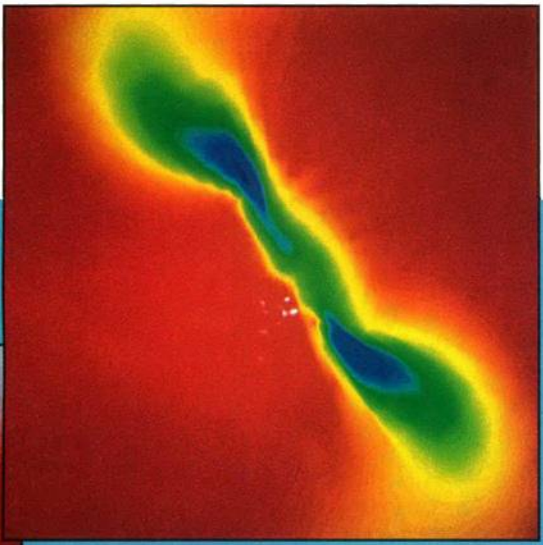
The Herschels were tireless observers who regularly scanned the heavens with 6-inch to 18-inch telescopes. In 1782, they began compiling a list of double stars that drifted through their eyepieces. The list grew and grew until it soon contained so many pairs of stars that it was highly unlikely they were all the result of chance alignments. Finally, having observed three separate pairs of stars for several decades, William Herschel proved that each pair was revolving about a common central point. When his same test was applied to other pairs on the list, some of them indeed turned out to be "optical" pairs — two stars that really were unassociated. But the bulk of the doubles passed the test with flying colors: they were true binary systems.

Dominating the Neighborhood

Why do astronomers think double and multiple stars are important? Simple — nature has made so many of them. Of the ordinary main-sequence stars in the disk of the Milky Way, most are members of binary or multiple systems, rather than single stars like our own Sun.

Recent work by two astronomers has given us more information about the makeup of those systems. A. Duquennoy and M. Mayor of the Geneva Observatory have studied all main-sequence stars similar to our Sun within 75 light-years. They learned that, in fact, most of these stars were not loners, but binaries, with companion stars of varied mass. In 65 percent of the pairs, the companion star was at least one tenth as massive as the primary star. (A primary star is the more luminous one in a pair or a system.) Another 18 percent were stars whose companion may have been of lesser mass.

Duquennoy and Mayor also found numerous multiple stars in their sample, both triple and quadruple systems. These multiple stars fall into either of two basic types: hierarchical and Trapezium. Most are "hierarchical": the system consists of two stars making a close binary pair, with a companion (which may be another tight binary pair) orbiting at a distance. Alpha Centauri, with its close A-B pair and the much more distant dwarf star, Proxima, falls into this category.



RECIPE FOR A BINARY STAR: COOL THE CLOUD THAT GIVES IT BIRTH

A cold, dusty cloud of gas is the starting point for astronomers when they try to computer-model how binary stars form. The cloud in this model is as massive as the Sun. It has a diameter of 550 astronomical units and is color-coded to show variations in density (blue is most dense, red is least).

The sequence of three images starting at far left shows that as astronomers lower the temperature in the collapsing model cloud, the outcome is a binary star rather than a single star. Notice the twin blue "cores" in the last image.

The second type, the "Trapezium" kind, is far less common. Named for the bright multiple star in the heart of the Orion Nebula, stars of this category typically have three or more stars orbiting together with roughly equal separations. Trapezium systems are rare because such a situation is highly unstable — eventually three of the stars will have a close encounter and one or two of them will be ejected. Astronomers usually find Trapezium systems in young star-forming regions like Orion, where the newborn systems have not yet had time to disintegrate. In contrast, hierarchical systems are dynamically stable and hence quite long-lived.

To a New Neighborhood

The survey of Duquennoy and Mayor looked only at mature stars. To probe the source of binaries, astronomers need to push back the age limits and examine much younger objects — the pre-main-sequence stars that have not yet fired up their thermonuclear furnaces. Robert Mathieu of the University of Wisconsin and his collaborators have found a number of spectroscopic binaries among the pre-main-sequence stars.

A spectroscopic binary is a binary system that lies far enough away that it appears in the eyepiece as a single star. But when this star is studied with a spectrograph, the lines in its spectrum periodically change position or split in two. This occurs when the orbital motion of the unseen companion star imparts a back-and-forth Doppler shift to the primary's spectral lines.

Astronomers have found such hidden binaries other ways too. Michal Simon of SUNY Stony Brook and Wen-Ping Chen of the Carnegie Institution of Washington have used lunar occultations to detect unseen companion stars in binaries. When the airless rocky limb of the Moon glides in front of an unresolved binary, it slices into the star's beam of light like the keenest of knife-edges. If the star is double and favorably aligned, one of its components will snap out of sight a fraction of an instant before the other. With an instrument that responds quickly enough, astronomers can see a clear pause in the signal as the light from the star drops to zero in two steps.

While Simon and Chen have observed relatively few stars as yet, their results show that binary systems occur among pre-main-sequence stars just as often as among the main sequence stars. This confirms the overall statistical frequency of binaries, but it also indicates that most or all binary stars are *born* that way, not made subsequently.

In pushing back toward younger and younger stars, astronomers run into an observational problem. The youngest protostars — stars still in the process of forming from their parent interstellar clouds — are swaddled in dense cocoons of dusty gas and are difficult to view. Astronomers expect, however, that new millimeter-wave radio telescopes — working at wavelengths that pass through the dust relatively unhindered — will soon "see" into such clouds and detect binary protostars. One such protobinary has already been found in the Rho Ophiuchi cloud by Alwyn Wootten of the National Radio Astronomy Observatory. The components in Wootten's protobinary orbit about 750 astronomical units apart, a typical value for binary stars, whose separations range from a few stellar radii to about 20,000 AU. (Earth orbits 1 AU from the Sun, and Pluto's average distance is 40 AUs.) Finding many more binary protostars would imply that binary systems may be created during star formation itself — the mysterious and imperfectly understood process that occurs when interstellar gas clouds collapse under gravity.

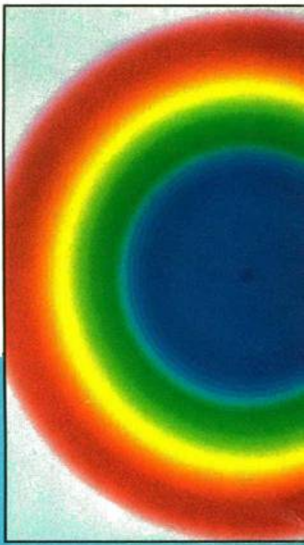
What is the Orbital Period for a Theory?

Reduced to its essence, understanding how binary stars form means learning how an interstellar gas cloud, a protostar, or a pre-main-sequence star can divide into two or more separate, self-gravitating bodies. We have seen that observations of very young binary stars are quite difficult at present because of the closeness of the objects to each other, the distance to the nearest star-forming regions, and the presence of intervening gas and dust that usually shield the process from view. Hence much of our understanding of binary star formation has come from theoretical work, particularly computer simulations.

As astronomers today juggle their complicated equations with supercomputers, they look back in wonderment at past efforts, which were often carried out with no computational means more sophisticated than pencil, paper, and logarithm tables. Theories for the formation of binary stars began almost as soon as the stars were recognized. Soon after the Herschels began finding large numbers of them, the French astronomer and mathematician Pierre Simon de Laplace suggested a separate-nuclei hypothesis for their origin. Laplace thought that binary stars might occur simply because their progenitors happened to be located close together.

Unfortunately, Laplace described his hypothesis so vaguely that it was largely ignored for two centuries. During the 1980s, however, the discovery of young stars and dense clumps of matter buried in interstellar clouds has resulted in a rebirth of Laplace's hypothesis, albeit in a different guise.

James Pringle of Cambridge University has suggested that these clumps should occasionally undergo

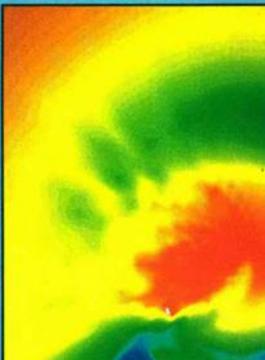


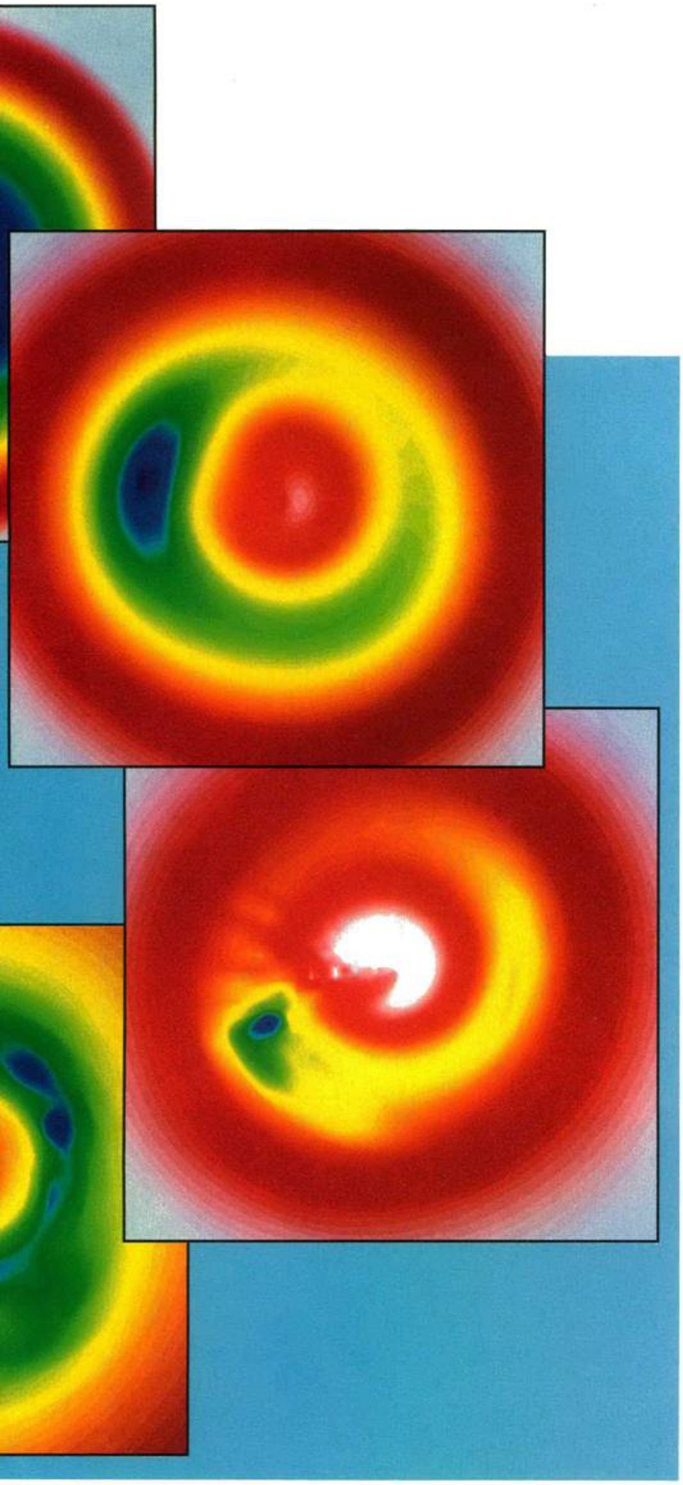
FROM SPHERE TO "BANANA" TO MULTIPLE STAR

Starting with a spherical cloud of cold, dusty gas (top), this model star system evolves into a multiple star. The diameter of the 1 solar mass cloud at the beginning is some 400 astronomical units, but this shrinks to about 250 by the last frame. (Blue denotes areas of highest density, red the lowest.)

The cloud first develops a banana-shaped region of high density as random motions cause the material to coalesce. Then other dense areas arise. The end result is a small group that will form a multiple star with three components. It's also possible that the large lump at about 8 o'clock in the bottom image would fragment in two.

Computer models show that multiple stars often take the form of a close binary pair and a distant companion. (Alpha Centauri, the star nearest to the Sun, has just this configuration.)





collisions with each other. The collisions should produce strongly compressed regions where the clouds collide, and these regions might then begin to collapse and lead to the formation of a binary system. Pringle's hypothesis has not yet been studied in detail, but the computer modeling of John Lattanzio at the Lawrence Livermore Laboratory and his collaborators appears to cast doubt upon it. Their work suggests that the outcome of cloud-clump collisions is more likely to be a roughly spherical cloud that may not collapse to form a binary system.

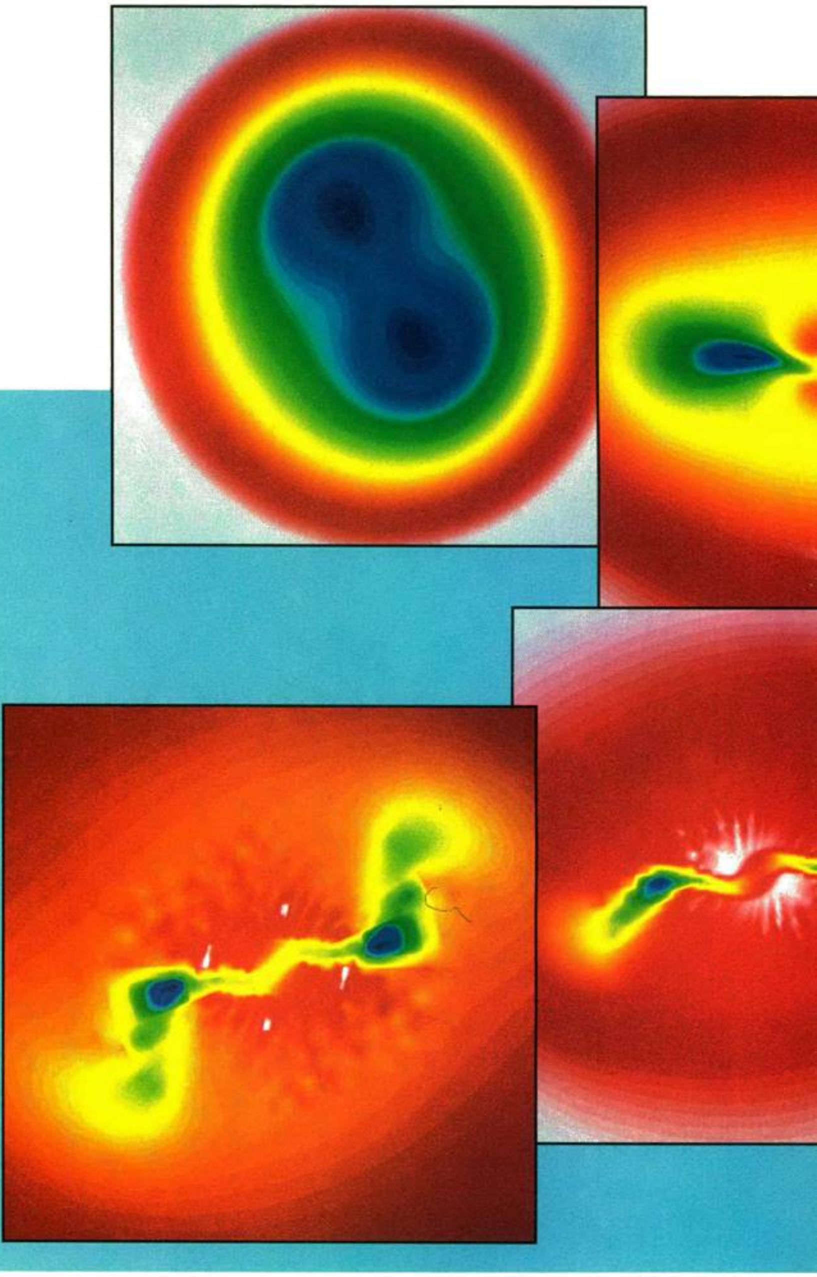
Another classical hypothesis for binary origin is capture, which posits that pre-existing single stars become trapped in a binary system. But captures are tricky. They can occur only if some mechanism exists to remove kinetic energy from the individual stars in the encounter. Otherwise the stars zip past each other on hairpin trajectories and fly apart like some kind of cosmic pinball game.

Theoreticians have proposed several mechanisms for dissipating kinetic energy. One is the three-body encounter, in which a third star is ejected and carries off the excess kinetic energy. Another is tidal dissipation, by which tides raised in each star during a close encounter rob energy from both. However, when astronomers calculate the probability of having the bodies come just close enough in exactly the right way, it turns out capture is an enormously improbable means of making binary stars — even in dense star clusters where close interactions will occur much more frequently than among the stars of the galactic disk.

Richard Larson of Yale University recently tried to revive the capture method. He pointed out that the friction experienced by a star passing through the gaseous disk of a protostar might soak up enough energy to trap the star and protostar into a binary orbit. While the frictional forces in this situation remain to be determined, astronomers think it's still unlikely that capture by this mechanism could happen frequently enough to be important — although an exception might perhaps occur in stellar clusters that are even denser than the Orion Nebula.

The final classical method is fission, long a favorite of scientists and mathematicians such as William Thomson (Lord Kelvin), George Darwin (son of Charles Darwin), James Jeans, and Henri Poincaré. The fission hypothesis, which had its heyday in the late 19th and early 20th centuries, is based on the notion that if a body spins fast enough it will fly apart. Scientists worked out the precise speeds of rotation at which bodies of uniform density would become unstable, but they were unsure exactly what form the instability would take. They hypothesized that because the instability begins with a tendency of the body to divide in two, this might very well continue and lead to the formation of a binary star.

The fission hypothesis may not be new, but it has attractive features. As a pre-main-sequence star contracts toward the main sequence, it will spin faster and faster, like a whirling skater who draws



PAIRS WITHIN PAIRS WITHIN PAIRS...

If the cold cloud of gas and dust has an elongated shape (as shown here at top center), the result often leads initially to a binary pair of stars, according to the computer models.

This cloud, which weighs as much as the Sun and has an initial diameter of more than 4,000 astronomical units, will first form a binary pair about 1,000 astronomical units apart. But both lumps are probably large enough to fragment again, which will create a binary hierarchy, with four stars grouped in two pairs of two (near right).

This kind of arrangement, gravitationally stable, can be found throughout the sky.

in her arms. If the protostar should spin fast enough, fission instability could develop and the star break in two.

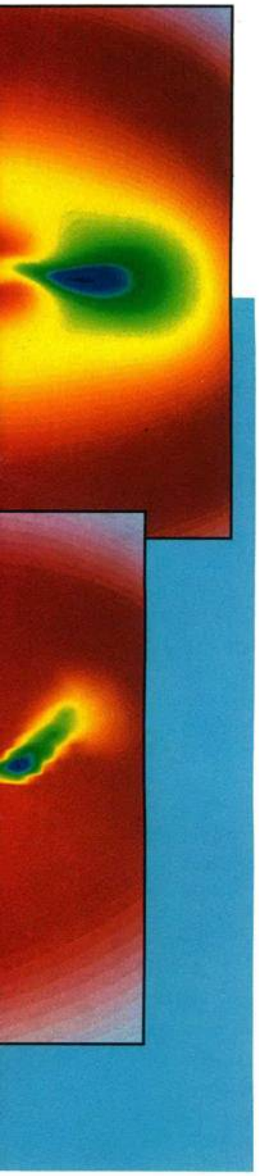
The hypothesis looks good enough that over the last decade astronomers spent much computer time modeling plausible outcomes for fission instabilities. Unfortunately, the results all show that fission does *not* lead to binary star formation. Instead, spiral arms form similar to those in spiral galaxies. As these expand, they remove angular momentum from the center of the body, lowering its rotation rate below the critical value for instability. The spiral arms then coalesce into a relatively low-mass disk in the equatorial plane of the body. Observational evidence backs up the calculations, because young protostars are known to have such disks. In fact, Earth and the other planets formed from just such a disk around the newborn Sun.

Another hypothesis has been put forward recently by Fred Adams of the Harvard-Smithsonian Center for Astrophysics. Together with Steven Ruden (University of California, Irvine), Frank Shu (University of California, Berkeley), and Scott Tremaine (Canadian Institute of Theoretical Astrophysics), Adams has suggested that the disks around very young stars will produce waves that look like bananas (see pages 38-39) rather than spirals. These bananas, they suggest, might eventually break up and form a second protostar in addition to the one already at the center. The result: a binary system.

This mechanism has not yet been investigated in sufficient detail to know if it works. But once again, this kind of instability shares similarities with fission instability and these hint at a similar — and equally negative — outcome.

Big Binary Star Machines

Over the last decade or so, I and many other astronomers worldwide have been developing computer programs — "codes," in the jargon — to study how



gas clouds can collapse and form stars. The codes involve the numerical solution of mathematical equations that determine the flow of gas, dust, and radiation in a cloud. The equations are similar to those used to predict weather on Earth. However, the astrophysical codes must also solve for the cloud's self-gravity, because it is gravity that ultimately holds each binary object together.

These programs are terrifically complex — they have to be if we want to model even modestly a 3-dimensional gas cloud light-years across — and they require large amounts of computer time on the fastest supercomputers available. (It's no accident that the research in the field has gone hand-in-hand with the development of super number-crunchers.) In addition to the computer code I have developed, many other similar codes have been developed independently by other astronomers.

The existence of independently written codes might look like a wasteful duplication of effort, but it confers huge benefits by permitting us to calculate the same theoretical model with each of our codes and to compare the results. In part because the codes are complex, we can't ever be completely certain how valid our results are, but comparisons let us sort out the real physics from the spurious. It's reassuring, however, to note a satisfying amount of agreement, including both codes that treat the cloud as a continuous fluid and codes that model the cloud as a collection of smoothed particles.

Today's most promising approach to the problem of how to make binary and multiple stars seems to be fragmentation. This refers to the possibility of an interstellar cloud's breaking up into two or more protostars during the time the cloud is collapsing. Almost forty years ago Fred Hoyle pointed out that as a gas and dust cloud collapses and becomes denser, objects of ever-smaller mass might be able to fragment out of it. The computer codes have been instrumental in discovering under what conditions a collapsing interstellar cloud is likely to produce a binary system.

Generally speaking, nature can make a binary star when the gas cloud is cold, its center is moderately condensed, it has appreciable rotation, and it is not controlled by magnetic fields. Unfortunately, observers have not yet been able to identify interstellar clouds that are now on the verge (or in the early phases) of collapse. Such observations will be critical for determining whether or not real clouds actually do begin to collapse from the configurations that fragmentation theory says are likely to lead to the formation of binary stars.

The illustrations show some of the possible outcomes for the collapse of interstellar clouds. When the initial cloud is strongly distorted and cigar-shaped — we have seen some of these in nature — the cloud tends to collapse and form a binary protostar. As each of these protostars undergoes its own collapse, a second phase of fragmentation may set in, forming a binary system on a smaller scale. This yields a hierarchical multiple system. But when the cloud is not as strongly distorted to begin with, it may collapse to form a ring-like structure that eventually fragments into a small number of protostars with varied masses. In this case, a Trapezium-style multiple system may result.

However successful, fragmentation is unlikely to be the last word in binary formation theory. But astronomers are finding it useful because it appears capable of explaining many kinds of binary and multiple stars as well as key properties of them, such as their tendency to have highly eccentric (noncircular) orbits and unequal masses.

A number of new computer codes have been developed in the last few years and are now being applied to the study of various problems associated with binary star formation. This is clear evidence for a resurgent interest in this difficult and abstruse field. New theory is being coupled with strong ongoing observation efforts aimed at detecting and describing young binary systems. We can look forward to seeing great progress in understanding these beautiful and intriguing stellar systems. □

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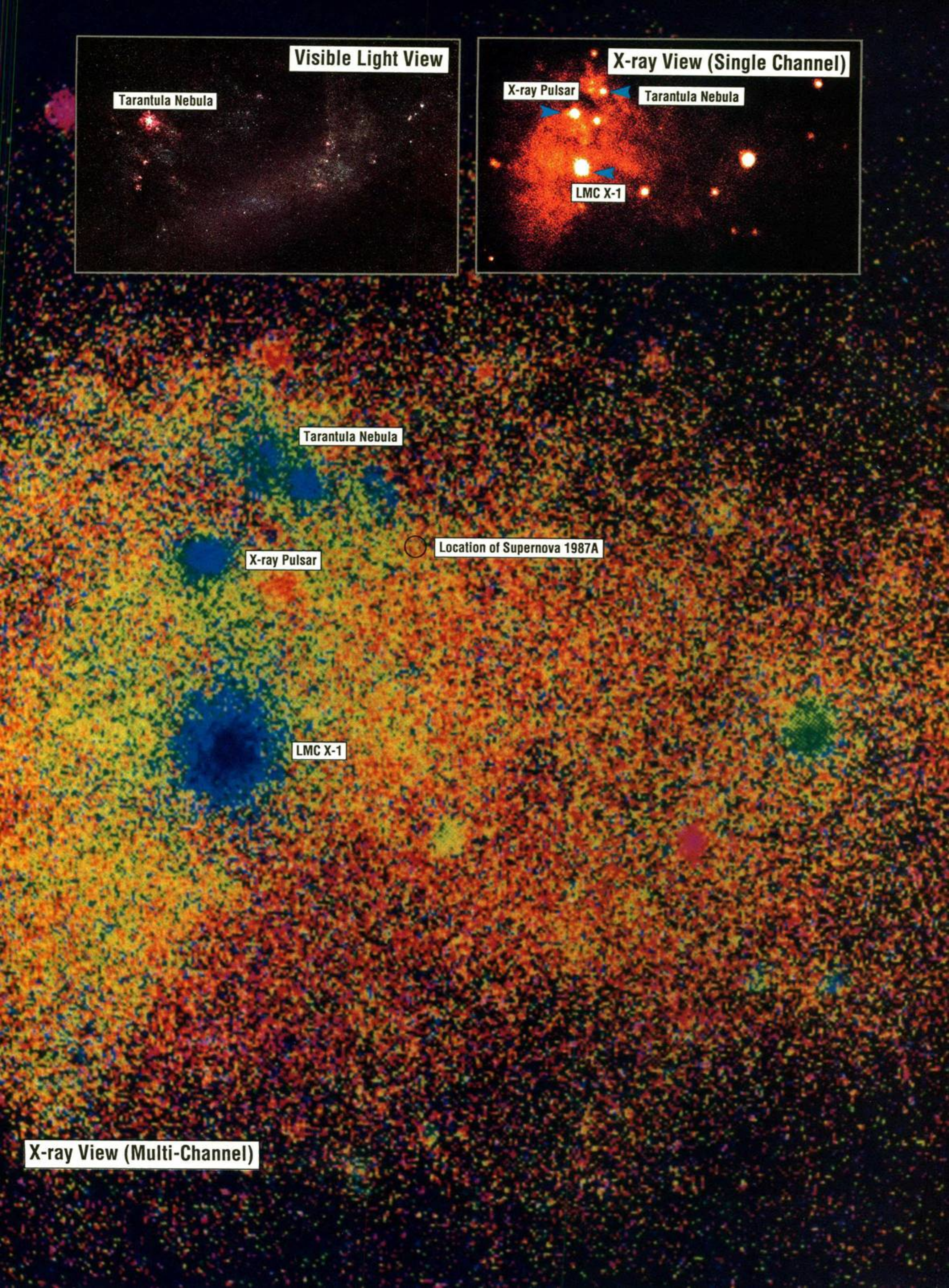
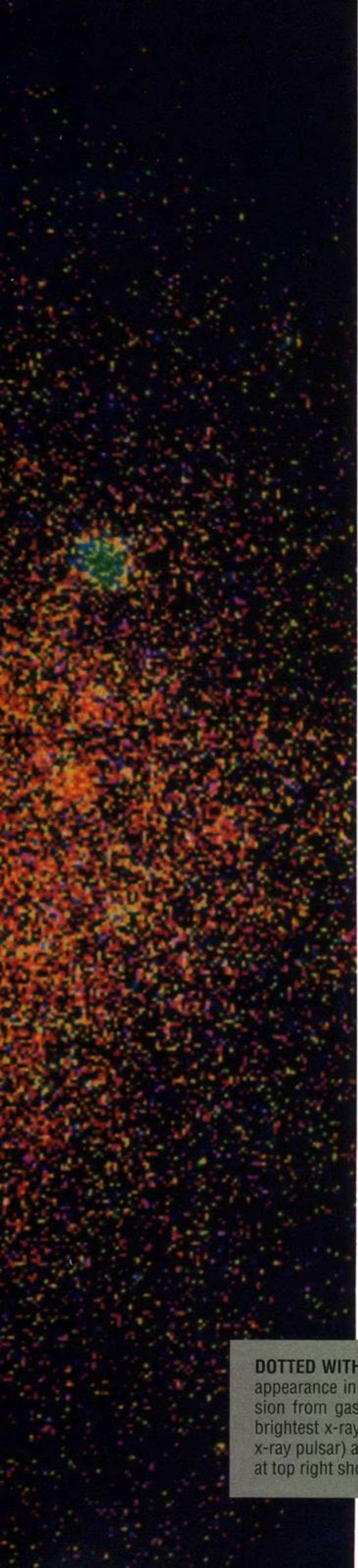

Visible Light View
Tarantula Nebula
X-ray View (Single Channel)
X-ray Pulsar
Tarantula Nebula
LMC X-1
Tarantula Nebula
Location of Supernova 1987A
X-ray Pulsar
LMC X-1
X-ray View (Multi-Channel)

ASTRONOMY FROM ORBIT

ROSAT's
Penetrating X-ray Visions

Last February, the orbiting ROSAT observatory completed the first task in its multi-year mission — a survey of the entire x-ray sky.

by Alan Dyer



DOTTED WITH X-RAY SOURCES, the Southern Hemisphere's Large Magellanic Cloud takes on a new appearance in this multi-color image taken by the ROSAT observatory. Red areas denote x-ray emission from gas at about 500,000 K, blue indicates temperatures as high as 10,000,000 K. The two brightest x-ray sources are the black hole candidate LMC X-1 and a rapidly spinning neutron star (the x-ray pulsar) above it. The inset at top left shows a visible light image with a comparable field. The inset at top right shows a ROSAT view taken in a single "color" that isolates only the hottest emission areas.

Superman's x-ray vision allowed him to see through walls and thwart the deeds of evil villains. The new x-ray vision that astronomers have acquired won't allow them to perform the deeds of comic book superheroes, but it is providing some super views of objects as exotic as black holes and as far away as the edge of the observable universe.

The new x-ray vision comes courtesy of ROSAT, an observatory orbiting 350 miles above the surface of Earth. After being launched with relatively little fanfare on June 1 of last year by a Douglas Delta II rocket, ROSAT has spent the last few months accomplishing what no other satellite before it had been able to do — take images of the entire x-ray sky. Earlier this year, on February 9, ROSAT completed its all-sky survey. The result was a flurry of excitement in the astronomical world about what ROSAT's x-ray eyes have revealed.

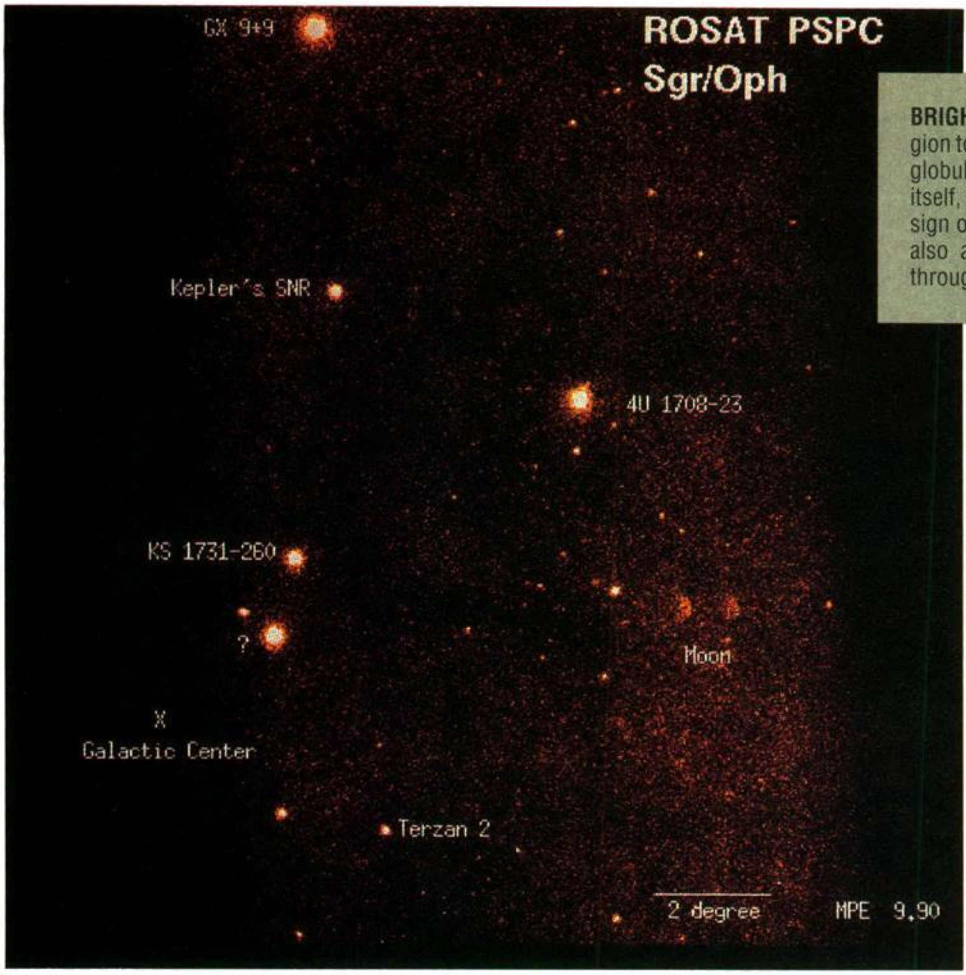
Prior to ROSAT, existing x-ray catalogs of the sky contained about 1,000 known objects. Astronomers estimate that the ROSAT survey has logged 100,000 x-ray sources. As U.S. project scientist Stephen Holt put it, "ROSAT is revealing lots of new supernova remnants, lots of new quasars, lots of new everything!"

Trapping X-rays

Some of the first efforts to observe the universe from above Earth's obscuring atmosphere were rocket flights with x-ray detectors on board. During their quick glances at the sky, these pioneering flights of the early 1960s discovered several intense sources of cosmic x-rays. This surprised doubters who had proclaimed x-ray astronomy a pointless pursuit. They couldn't imagine how any celestial object could generate x-rays strong enough to detect. Of course, the doubters were wrong. As early efforts to get instruments above the atmosphere proved, the universe is shining with x-ray as well as other wavelengths invisible to our limited sight.

Through the 1970s and '80s evermore sophisticated x-ray satellites were fired into orbit, each contributing new details to our view of the x-ray universe. The roster of missions included the British-built Ariel-5 and Uhuru satellites, NASA's High Energy Astrophysical Observatories, the European EXOSAT, and the Japanese Ginga satellite.

The last NASA mission to study x-rays was the Einstein Observatory, number two in the series of three High-Energy Astrophysical Observatories. Launched in 1979, the Einstein satellite didn't just measure the amount and direction of incoming x-rays as previous satellites and rocket-borne detectors had done; it produced the first true images of x-ray objects. But Einstein looked only at selected targets, ones already discovered by previous missions. Astronomers wondered about the x-ray objects they had yet to find, let alone



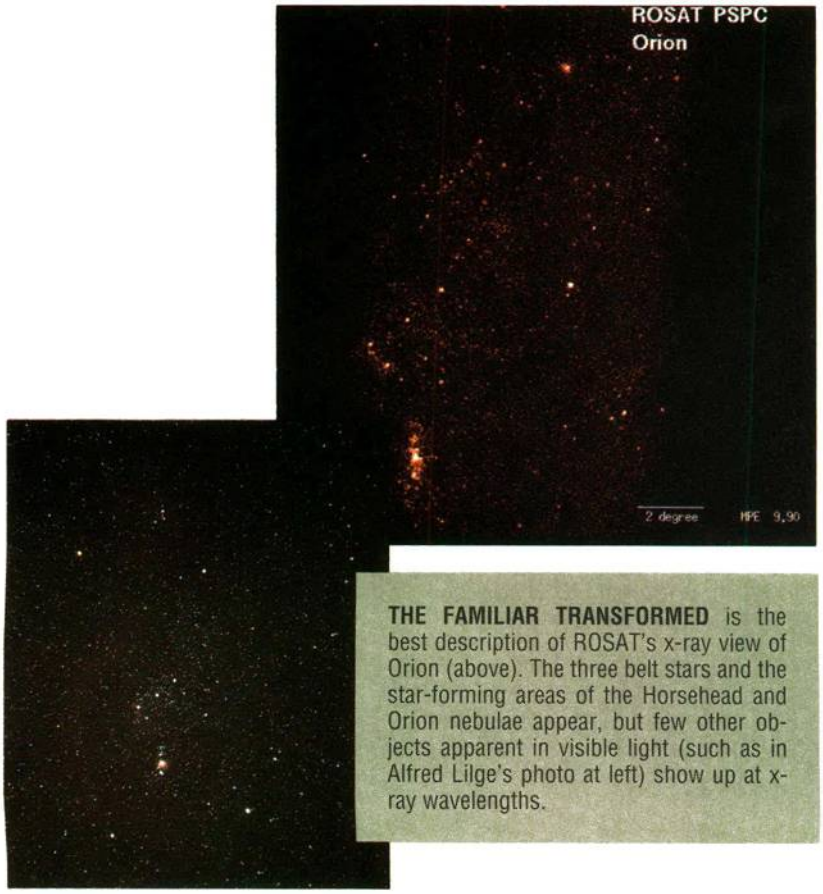
BRIGHT BLOBS OF X-RAY EMISSION dot the region toward the center of the Galaxy. Most are from globular clusters of stars. The center of the Galaxy itself, just off the edge of this frame, showed no sign of x-ray emission. The Moon's ghostly image also appears twice on this image as it passed through the frame.

see in any detail. What kinds of objects would they be? How many were there? How were they distributed about the sky? To answer those questions, astronomers designed ROSAT. This latest generation of x-ray observatory brings the power of an imaging telescope to the task of surveying the entire sky searching for new targets. ROSAT not only detects objects; it also takes images of them.

ROSAT is a joint project of NASA, the U. S. Air Force, Great Britain, and Germany, represented by the Max Planck Institute for Extraterrestrial Physics. (The name ROSAT comes from the German word "Röntgensatellit" and honors the German physicist Wilhelm Roentgen who discovered x-rays in 1895.) Time on ROSAT is split among the three main nations that built and launched the satellite: U. S. astronomers get 50 percent of the observing time, German astronomers 38 percent, and British astronomers 12 percent.

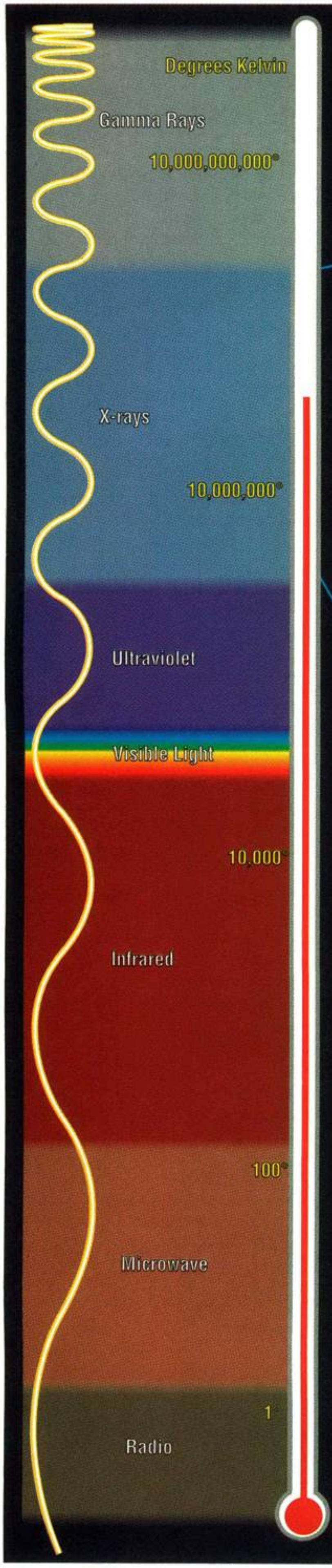
At the heart of ROSAT is its 33-inch diameter "grazing incidence" telescope. You can't use normal glass mirrors to reflect and focus high-energy wavelengths such as x-rays. Instead, the ROSAT telescope uses a series of four nested metal tubes. The incoming x-rays glance off the polished walls of these tubes at shallow angles and are deflected to a focus at the rear of the tube assembly. The x-rays are channeled into the focal point where a detector measures and records their strengths, frequencies, times of entry, and angles of origin.

ROSAT can place one of three detectors at its focus: two nearly identical units called Position Sensitive Proportional Counters and a third unit called the High-Resolution Imager. The German-built Proportional Counters can resolve objects as small as 30 arcseconds across, roughly the apparent diameter of Jupiter. They can see as much as 2 degrees of the sky at a time, a field four times the diameter of the Full Moon. These Counters were the



THE FAMILIAR TRANSFORMED is the best description of ROSAT's x-ray view of Orion (above). The three belt stars and the star-forming areas of the Horsehead and Orion nebulae appear, but few other objects apparent in visible light (such as in Alfred Lilge's photo at left) show up at x-ray wavelengths.

The X-ray Universe



X-rays are generated at ultra-high-temperatures. For example, atoms in the Sun's outer atmosphere, the corona, are at temperatures of 1,000,000° K and are strong emitters of x-rays. Some of the most dramatic images of the solar corona were taken in 1973 by an x-ray telescope on board the manned Skylab space station.

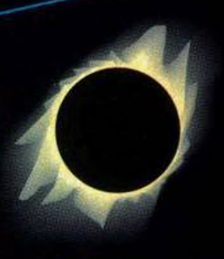
Other stars can also emit x-rays. Hot stars blast winds of star-stuff into space where it collides with interstellar material. The shock waves generate x-rays. Surprisingly, cool stars can also be sources of x-rays. We know the Sun is, but some stars have even more active magnetic fields than the Sun. These "magnetic variable" stars are thought to be plagued by gigantic starspots and intense magnetic fields that churn the plasma in their outer atmospheres, heating it to millions of degrees. Capella, a star shown on one of the ROSAT frames, is such an x-ray star.

When stars explode as supernovae, their outer shells create shock waves of expanding debris. Often, the only indication of an ancient supernova remnant is a circular patch of x-ray-emitting debris. ROSAT has discovered many new supernovae remnants that were previously undetected by radio or optical telescopes.

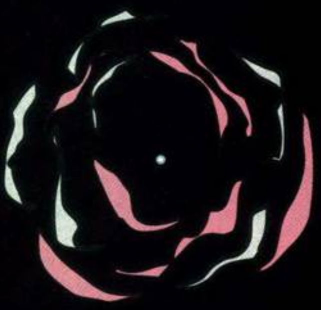
Black holes and neutron stars can also spark x-rays. The gas spiralling around these gravitational sinks becomes superheated. Indeed, the x-ray emission from some of these objects is the telltale sign of the presence of an otherwise invisible black hole.

Clusters of galaxies are another common source of x-rays. Some x-rays come from powerhouse objects, perhaps giant black holes, at the centers of the clusters' biggest galaxies. Other cluster emission comes from hot gas permeating the intra-cluster space, gas stripped from member galaxies during tortured galactic collisions.

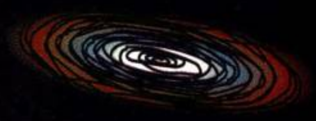
Not far removed from active galaxies are the quasars, thought to be galactic cores in the early stages of formation. Almost all quasars emit some level of x-rays. In fact, out of any random sampling of x-ray sources, 50 percent are likely to be quasars. Quasars are the most distant discrete objects we can see. Studying their all-important x-ray signatures will provide clues to their origin and in turn the origin of galaxies and the visible universe.



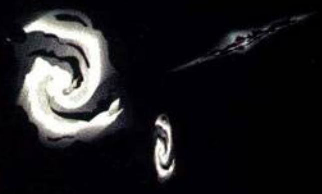
Stellar Atmospheres



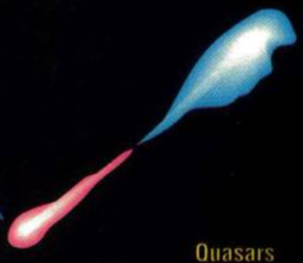
Supernova Remnants



Black Holes



Galaxy Clusters



Quasars

T.HUNT

main detectors used during the all-sky survey. The U. S.-built High-Resolution Imager is not as sensitive as the Counters but can create images showing details down to 5 arcseconds across over a field of view about a quarter the size that of the Counters. The images from this device promise to be some of ROSAT's finest and certainly the sharpest x-ray images produced to date by any satellite.

The "high-res" detector can also resolve incoming x-rays by time. It can differentiate between x-rays arriving as fast as 60 millionths of a second apart. This high resolution in time enables astronomers to watch for flickering in the x-ray intensity coming from sources like black hole accretion disks, giving us clues to the size and structure of these revolving disks of superhot material.

The background glow may be from quasars at the edge of the visible universe.

ROSAT's x-ray instruments are sensitive to what are called "soft" x-rays, ones that have a relatively low energy of 0.1 to 2 kiloelectron volts (keV). This corresponds to a wavelength band of 100 to 6 Ångstroms. (By comparison, the shortest wavelength our eyes can detect is about 4000 Ångstroms.) X-rays with wavelengths shorter than 6 Ångstroms have higher energies and are labelled "hard" x-rays. Mapping the universe at those wavelengths and beyond will be the domain of this year's Gamma Ray Observatory mission and the Advanced X-ray Astrophysics Facility, scheduled for launch later in the decade.

A Thousand Points of Light

Hitching a ride on ROSAT is a related telescope called the Wide Field Camera. This British-built device detects photons with wavelengths on the long side of x-rays, a region called the extreme ultraviolet, or XUV band. To be precise, the Wide Field Camera works from 300 to 60 Ångstroms, a band rarely explored before. In fact, so pristine is this territory of the spectrum that, prior to ROSAT, only a dozen deep-sky objects were known to be sources of extreme ultraviolet light. With the completion of its all-sky survey, ROSAT has increased that number to nearly 1,000 XUV sources — "a thousand points of ultraviolet light" as one ROSAT astronomer quipped.

However, the number of new objects discovered in the XUV band is not as great as in the x-ray band, and for good reason. Hydrogen clouds between the stars absorb extreme ultraviolet photons, effectively blocking XUV radiation from distant sources. This fogginess of the XUV sky means astronomers can only see out to several hundred light-years at these wavelengths, restricting our view to our local neighborhood of the Galaxy. More distant sources will be visible at XUV wavelengths only if they are powerful enough to penetrate the hydrogen fog.

Since its domain is closer to home than the x-ray telescope's is, one of the prime missions of the Wide Field Camera will be to look for nearby white dwarf stars that are so hot they emit most of their energy in the XUV band instead of as visible light. The suspicion is that there may be many more such stars in the Galaxy than we have estimated so far.

To date, of the nearly 1,000 XUV objects they've detected, British astronomers have identified about 170 as being known targets that we can also see in visible light. Some are white dwarfs; some may be interacting binary stars. But it's the unidentified sources that may hold the most surprises. As Wide Field Camera researcher Kenneth Pounds points out, "Scientifically, the real payoff will come when we start to chase down the counterparts to the objects that are not obvious in visible light." Identifying these unknown sources will be the most exciting area of research.

First Impressions of the X-ray Sky

In late January, near the end of the all-sky survey process, mission scientists released a selection of ROSAT's greatest hits. These images demonstrate the variety of targets that emit x-rays. One well-known target, however, didn't show up. Although astronomers have long postulated that some type of high-energy object (a cluster of supermassive stars or perhaps a giant black hole) lurks at the center of our Galaxy, there is no sign of it on ROSAT's survey photos.

As Holt asserts, "We cannot see into the center of the Galaxy with ROSAT. At 2 keV the interstellar gas is very thick to x-rays." The Galaxy's core may be a profuse emitter of x-rays but the dense clouds between us and the heart of the Milky Way effectively absorb those emissions.

The image of southern Ophiuchus (see page 44), a section of sky near the direction of the galactic core, *does* show several intense sources. Most are globular star clusters whose x-ray emissions may come from gas swirling around black holes or from other processes as yet unidentified. One source is the remnant of the supernova recorded by Johannes Kepler in 1604, five years before Galileo first turned a telescope on the heavens. Nearly four centuries later what's left of Kepler's Supernova has become the target for a telescope that neither Kepler nor Galileo could ever have envisioned.

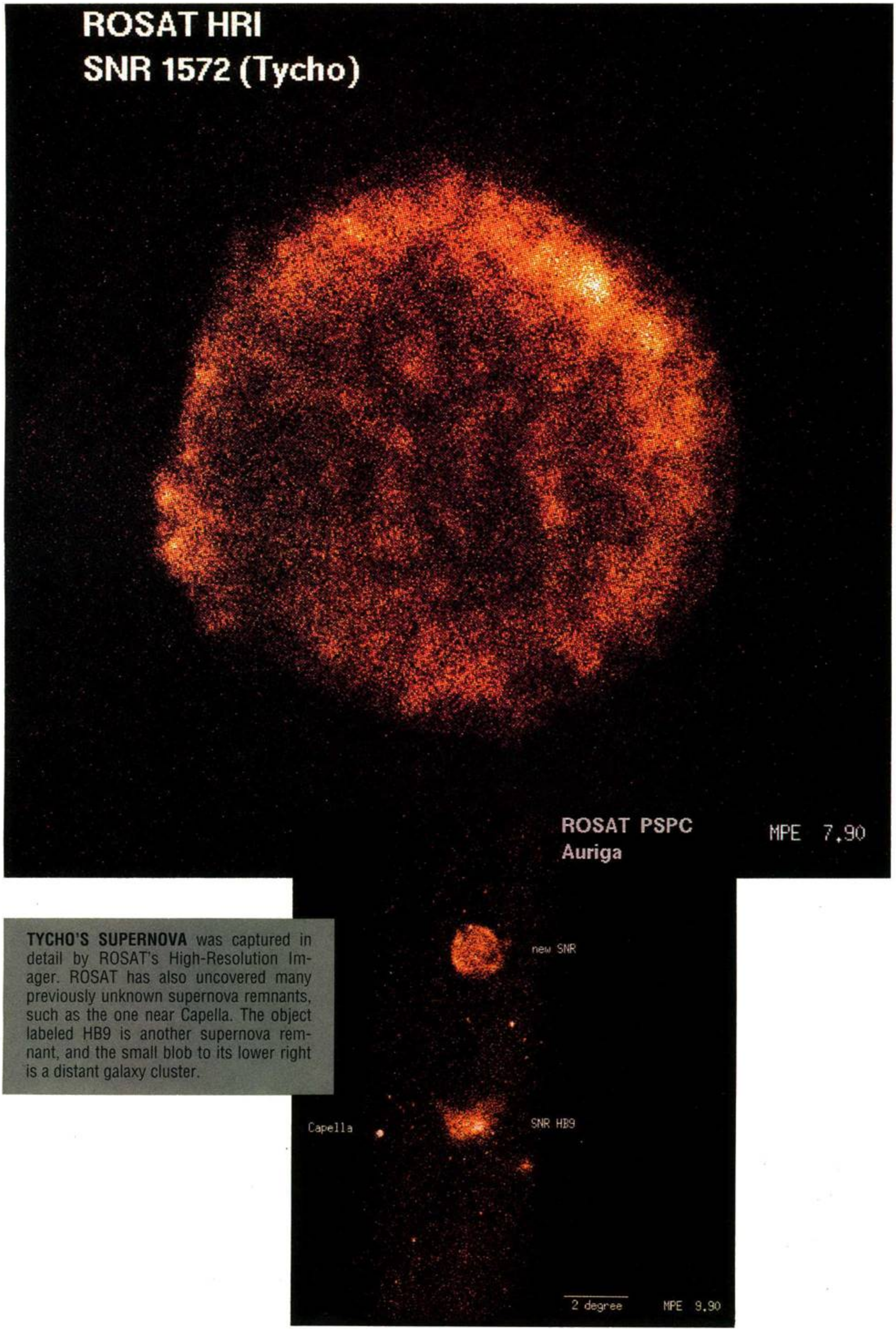
ROSAT captured a supernova remnant that bears the name of another giant of astronomy, Tycho Brahe. Tycho's Supernova, which exploded in 1572, has left behind a cloud of debris now invisible at optical wavelengths. But ROSAT's High-Resolution Imager shows the circular shell created as the expanding shock wave smashes into the surrounding interstellar gas at 150 times the speed of sound. The impact generates temperatures of millions of degrees — and with it, x-rays.

Supernova remnants are an easy catch for ROSAT. Its survey has already come up with dozens of such relics that had gone undetected up to now. One of them turned up near the bright star Capella in the constellation Auriga (at right). This shell is thought to mark the graveyard of a star that exploded 20,000 years ago.

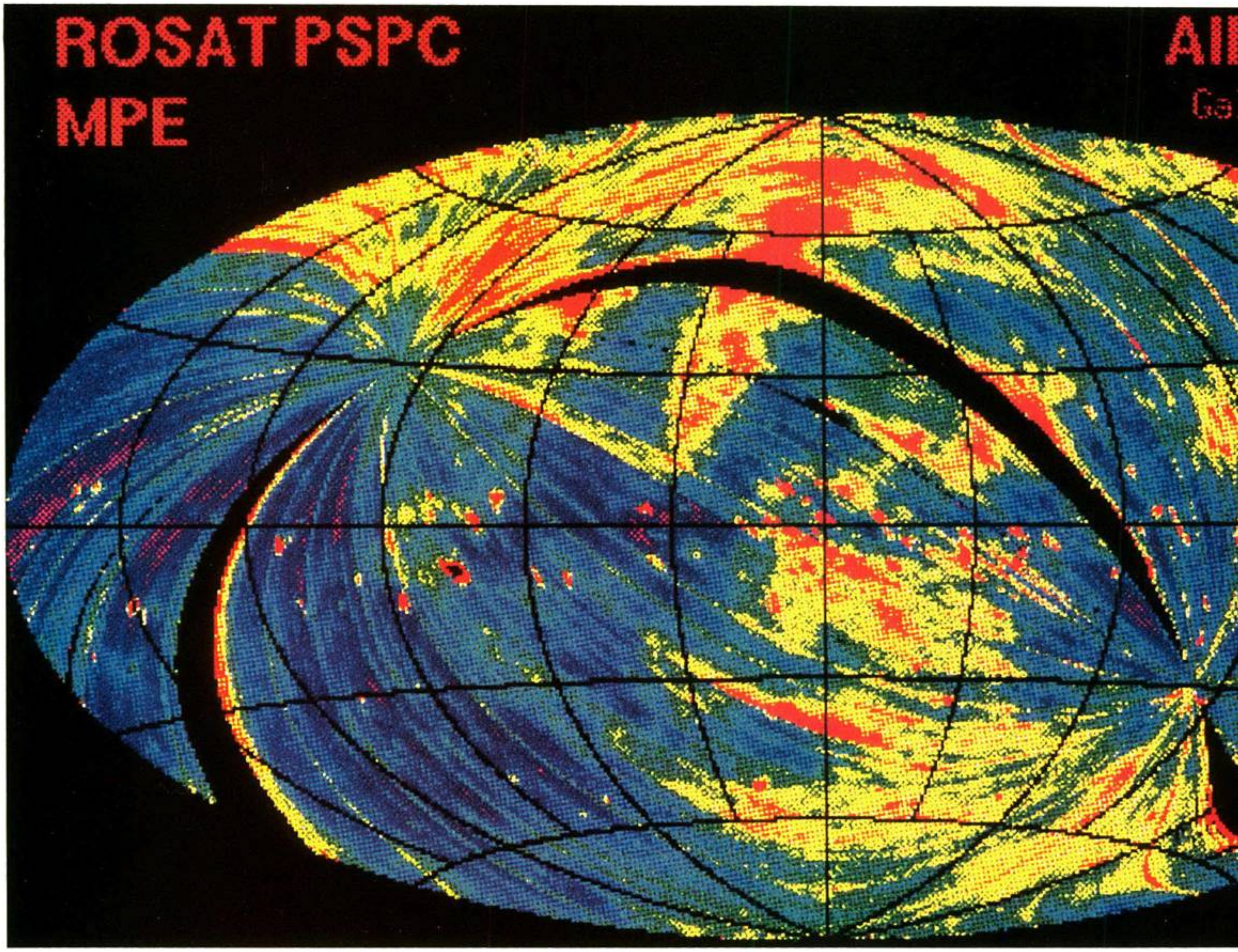
A target area rich in x-ray sources is the Large Magellanic Cloud, one of the companion galaxies to the Milky Way. The brightest of the 40 or so x-ray sources ROSAT catalogued in the Large Cloud is an object that barely shows up at visible wavelengths. LMC X-1, as it is known, is thought to be a system composed of an ordinary star that has the unfortunate fate of orbiting a black hole. The hole's gravity is tearing material off the star, a common process for creating x-rays.

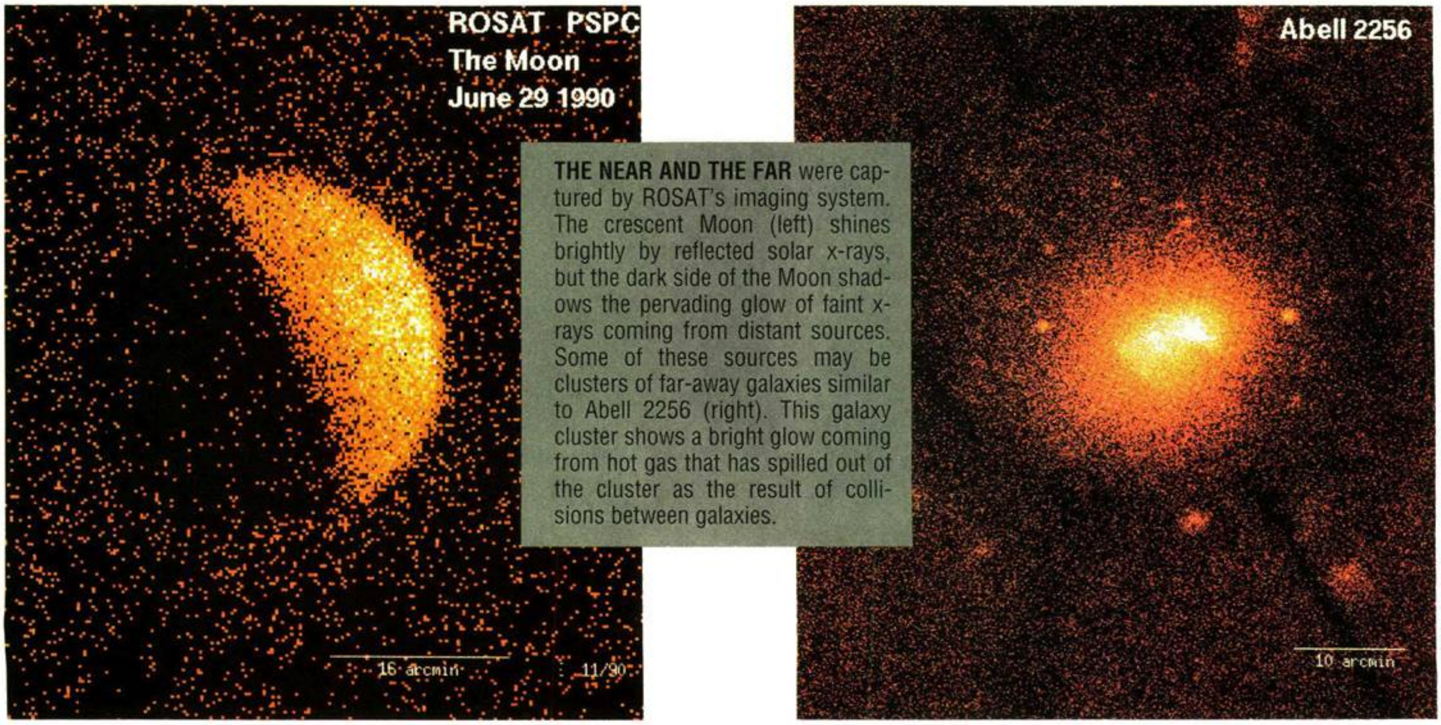
Just above LMC X-1 (see page 42) is an x-ray pulsar, a rapidly spinning neutron star that whips a beam of focused x-rays past us as it spins 20 times a second. ROSAT detected a sudden change in the spin rate of this pulsar that was one of the largest such glitches ever seen in the rotation rate of any pulsar. It was 100 times greater than the glitches seen in the famous Crab Nebula pulsar, one of the youngest in the sky. What causes these spin-rate glitches is not yet understood.

The Large Magellanic Cloud is also home to Supernova 1987A. ROSAT could not see any x-rays coming

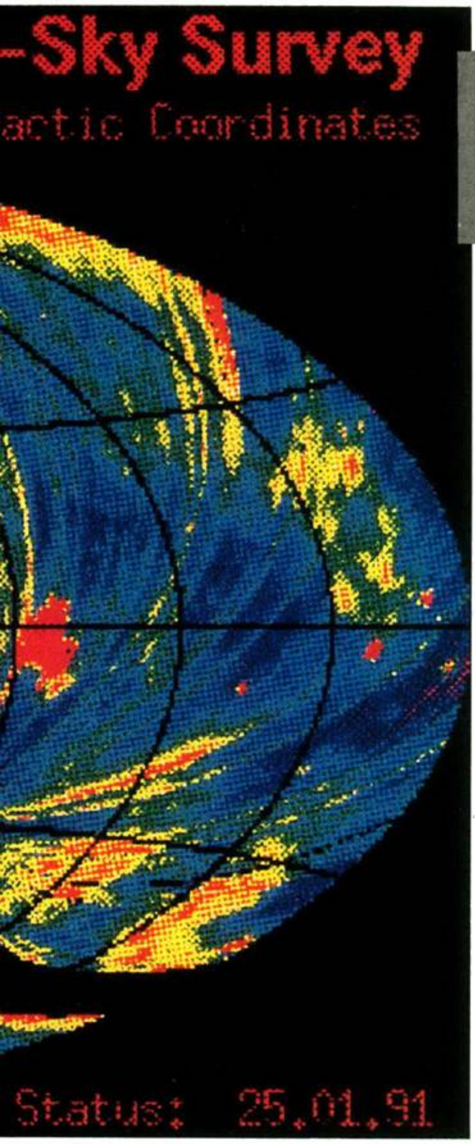

ROSAT HRI
SNR 1572 (Tycho)
ROSAT PSPC
Auriga
MPE 7.90
new SNR
Capella
SNR HB9
2 degree
MPE 9.90

TYCHO'S SUPERNOVA was captured in detail by ROSAT's High-Resolution Imager. ROSAT has also uncovered many previously unknown supernova remnants, such as the one near Capella. The object labeled HB9 is another supernova remnant, and the small blob to its lower right is a distant galaxy cluster.


ROSAT PSPC
MPE


ROSAT PSPC
The Moon
June 29 1990
16 arcmin
11/90
Abell 2256
10 arcmin

THE NEAR AND THE FAR were captured by ROSAT's imaging system. The crescent Moon (left) shines brightly by reflected solar x-rays, but the dark side of the Moon shadows the pervading glow of faint x-rays coming from distant sources. Some of these sources may be clusters of far-away galaxies similar to Abell 2256 (right). This galaxy cluster shows a bright glow coming from hot gas that has spilled out of the cluster as the result of collisions between galaxies.



THE BIG PICTURE of the x-ray sky was compiled as ROSAT scanned the heavens along great circles in swaths 2 degrees wide. The resulting sky map, shown with the equator of our Galaxy across the middle, shows areas of intense x-ray emission as red. The large band of red in the middle near the top is the North Polar Spur, thought to be the remains of a nearby million-year-old supernova.

from this four-year-old supernova remnant. It is still too early, for the x-ray emitting neutron star that was probably created by the force of the explosion is still shrouded in dense debris that is blocking the x-rays. As Holt explained, "The same kind of opacity that hides the galactic core is at work around the supernova. As the debris clears, I expect it will become a dynamite x-ray source in the next century."

As Far as the Eye Can See — Quasars

One of ROSAT's most exciting finds came from its images of blank areas of the sky. This sounds puzzling at first, but x-ray astronomers are quick to point out that at x-ray wavelengths the sky is far from being dark. Everywhere ROSAT looked it saw the sky lit by a diffuse glow. You can see the glow clearly in ROSAT's image of the crescent Moon on page 48. The sunlit part of the Moon's disk shines in reflected solar x-rays. But the dark side of the Moon is truly dark, much darker than the surrounding sky. Something spread across the depths of space is emitting a low level of x-rays. Discovered in the early 1960s, this background emission has long been a mystery.

To explore the background glow, ROSAT aimed at empty fields that contained no known x-ray sources and exposed for up to half a day. The results revealed that the background glow seems to be coming from vast numbers of the faintest x-ray sources ever seen. According to Max Planck Institute scientist Guenther Hasinger, "We estimate there are about 100 sources per square degree or 4,000,000 sources distributed over the whole sky." But Hasinger explained that there is a still more diffuse background glow between those sources. "The deeper we go the more sources show up."

The identity of the sources is still uncertain, but the best bet is that they are quasars. If so, these are quasars almost at the edge of the visible universe. They represent the energetic cores of galaxies formed early in the life of the universe billions of years ago. If the background glow is indeed from quasars, then ROSAT has provided a major find, for the quasars are not uniformly distributed across distant space but appear to be gathered in clumps. This was not expected.

Galaxies come in clusters, and those clusters are arranged in strings, walls, and even larger clusters across the sky. But most theories of the origin of the universe predict that this large-scale structuring of matter didn't occur until fairly late in the formation of the universe. With ROSAT, astronomers think they may be seeing glimpses of large-scale structuring at a cosmic era earlier than predicted.

NASA's Cosmic Background Explorer satellite, for example, shows that before the era of quasars, the universe was smooth, with no indication of clumping or structure (see "Too Smooth: COBE's Perfect Universe", June 1990). How, then, did quasars cluster together so early in the life of the universe? If this interpretation of the ROSAT data is true — if distant quasars are indeed clustered like nearby galaxies — then cosmologists will have to revise their theories of how galaxies formed out of the primeval soup of subatomic particles created in the Big Bang.

However, it is too early to make any conclusions. As Holt cautioned, "The interpretation of these background sources is difficult at best. Are these sources actually far away? They could be dim stars nearby. We have no direct evidence yet that these are in fact distant quasars. For example, in the Einstein satellite's deep images, lots of faint sources turned out to be just stars. To settle the question we'll need to take ground- or space-based spectra of these objects to measure their redshift."

Some of the controversy may be cleared up during phase 2 of the ROSAT mission as it goes back over its newly charted territory taking high-resolution images of about 1,000 selected targets. It will resolve some of the clusters of quasars, if indeed that's what they are. It will pinpoint targets with sufficient accuracy to allow radio and optical astronomers to aim their telescopes at suspect objects.

This "pointed observation" phase is expected to last about two years, provided all goes well. Things didn't go well for a few days in late January when ROSAT inexplicably spun out of control. An upset in one of the satellite's attitude control computers sent ROSAT drifting in the wrong direction. Ironically, the upset may have been caused by charged particles from a solar flare, an event that is itself a source of x-rays.

As luck would have it, during the crisis ROSAT accidently aimed at the Sun, which quickly burned one of the Proportional Counters. Fortunately, the second Counter can be used as a backup, so despite the technical problems the ROSAT mission can go ahead as planned.

Though now slightly blinded by the accident, the x-ray vision that ROSAT has given astronomers promises to continue revealing new marvels. Astronomers can't see through walls with ROSAT, but they can penetrate the mysteries of deep-space. ☐

Seeing the World through Infrared Eyes

We live in a world defined by visible light. Now imagine one in which we see not visible light, but infrared radiation. Prepare for a world in which skies are both placid and violent.

by Neil F. Comins

Each morning we awake to see the Sun rise and cast its golden light over rolling landscapes of green grass and tawny brown hills. The world is alive with action as people hustle to work and go through their lives, returning home as the Sun goes down. Our everyday world is awash with visible light, and sight dominates how we experience the world — our sensory experiences, interactions, and perceptions. The same is true of our view of the cosmos. When we look into the sky, we see the universe as it appears in visible light and don't see much that is violently active in other parts of the spectrum.

Visible light is a very sensible thing to be able to see, because it's the primary kind of radiation given off by the Sun and other stars. But visible light constitutes a tiny part of the electromagnetic spectrum and only one of many types of radiation permeating the world and the universe. The other radiation we can easily sense is infrared radiation, or heat. It is crucial to our existence and bathes us constantly, yet remains invisible. Also omnipresent yet invisible are other wavelengths of electromagnetic radiation — ultraviolet, x-rays, gamma rays, and radio waves. Ultraviolet just burns us, x-rays pass through us, we can't sense gamma rays, and we can detect radio waves only indirectly. The only type of radiation other than visible light that might benefit our eyes is infrared. Let's explore what our world might look like if our eyes showed us this infrared radiation. We'll discuss the possibilities that would confront us in an infrared world and consider just how our view of the solar system, the Galaxy, and the universe would change as seen in infrared.

Before we switch on our infrared eyes, let's establish the nature of the

Imagine that two asteroids grazed each other in a distant corner of the solar system. Our infrared eyes would see a bright burst of light that spreads out and darkens as the debris cools.

hypothetical world we will live in. Our first assumption is that the laws of physics exist exactly as they do now and are constant everywhere in the universe. Taking that as a given, we'll peer into a strange new world with two different scenarios. The first is that we exist exactly as we do now but can detect other wavelengths in the electromagnetic spectrum. That being the case, what is it, exactly, we would be able to see? As a second layer of exploration, we'll consider how our bodies might have to change to see other types of radiation.

To begin, let's consider the nature of radiation and what we see. Every photon, or particle of radiation, has a certain energy. The higher the photon's energy, the shorter the wavelength of radiation. Gamma rays, x-rays, and most ultraviolet radiation have the shortest wavelengths and thus, the highest energies. In fact they are energetic enough to rip electrons away from atoms, which makes them dangerous to living things. Fortunately, Earth's atmosphere prevents photons of these wavelengths from reaching the ground. Without this protective shield, long ago life would have had to make significant adaptations for survival. Actually, if continuously bombarded by these high-energy photons, complex, multicellular life as we know it might never have gained a foothold on Earth.

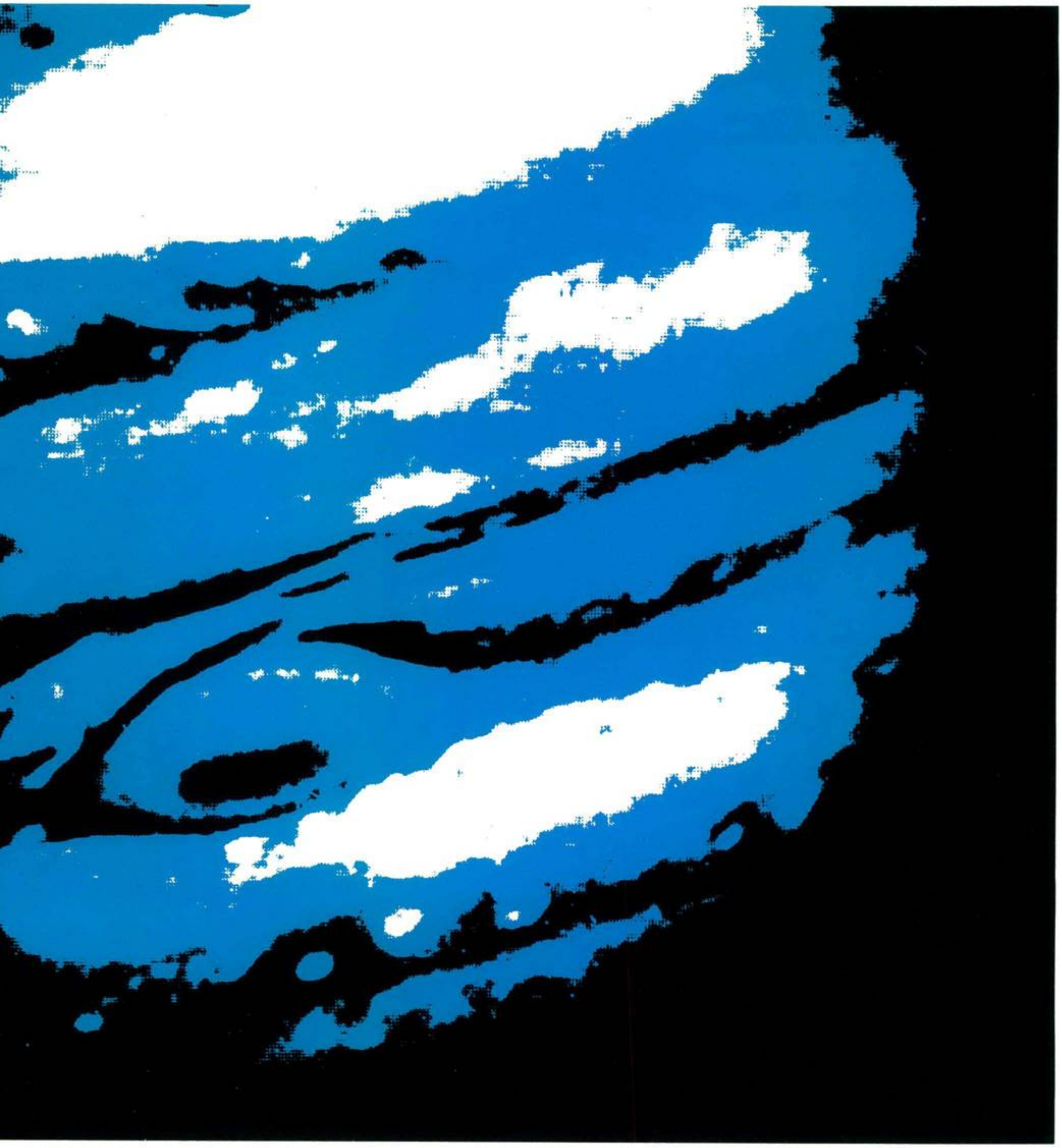
If our eyes could pick up this radiation, however, what would they see? Gamma rays don't naturally exist on Earth, so gamma-ray eyes would pick up little. Even if we had them, as I mentioned above, they would be quickly destroyed by the radiation they were supposed to detect. X-rays do occur naturally on Earth because of the decay of radioactive elements such as uranium, plutonium, thorium, and radon. However, these are extremely weak sources and they travel only a few yards before being absorbed. Remember also, that they too would destroy eyes sensitive to them. High-energy ultraviolet radiation has few natural sources on Earth. But some of this radiation does travel through the air and penetrates the ozone layer. In large doses, this is lethal, too. So with gamma rays, x-rays, and high-energy ultraviolet, we'd be better off with well-developed senses of smell or hearing, because our eyes would be little help in getting around.

Low-energy ultraviolet (called near ultraviolet) photons have wavelengths just shorter than our color purple, pass through Earth's atmosphere, and provide us with suntans and sunburns. Numerous insects like honeybees have developed ultraviolet-sensitive eyes at the cost of seeing red, orange, and yellow. Because many flowers have petals that reflect ultraviolet light, it makes sense that some insects' eyes detect that radiation. But humans don't detect such radiation, for ultraviolet emission from the Sun is weak.

Also, ultraviolet light does not reflect well from most objects. Flower petals do scatter ultraviolet light. But few other things in the world scatter ultraviolet light as well as flowers do. So ultraviolet eyes bring with them shortcomings of the ultraviolet spectrum like low intensity and poor scattering. And remember, too, it has harmful levels of energy. In short, ultraviolet eyes wouldn't do us much good.

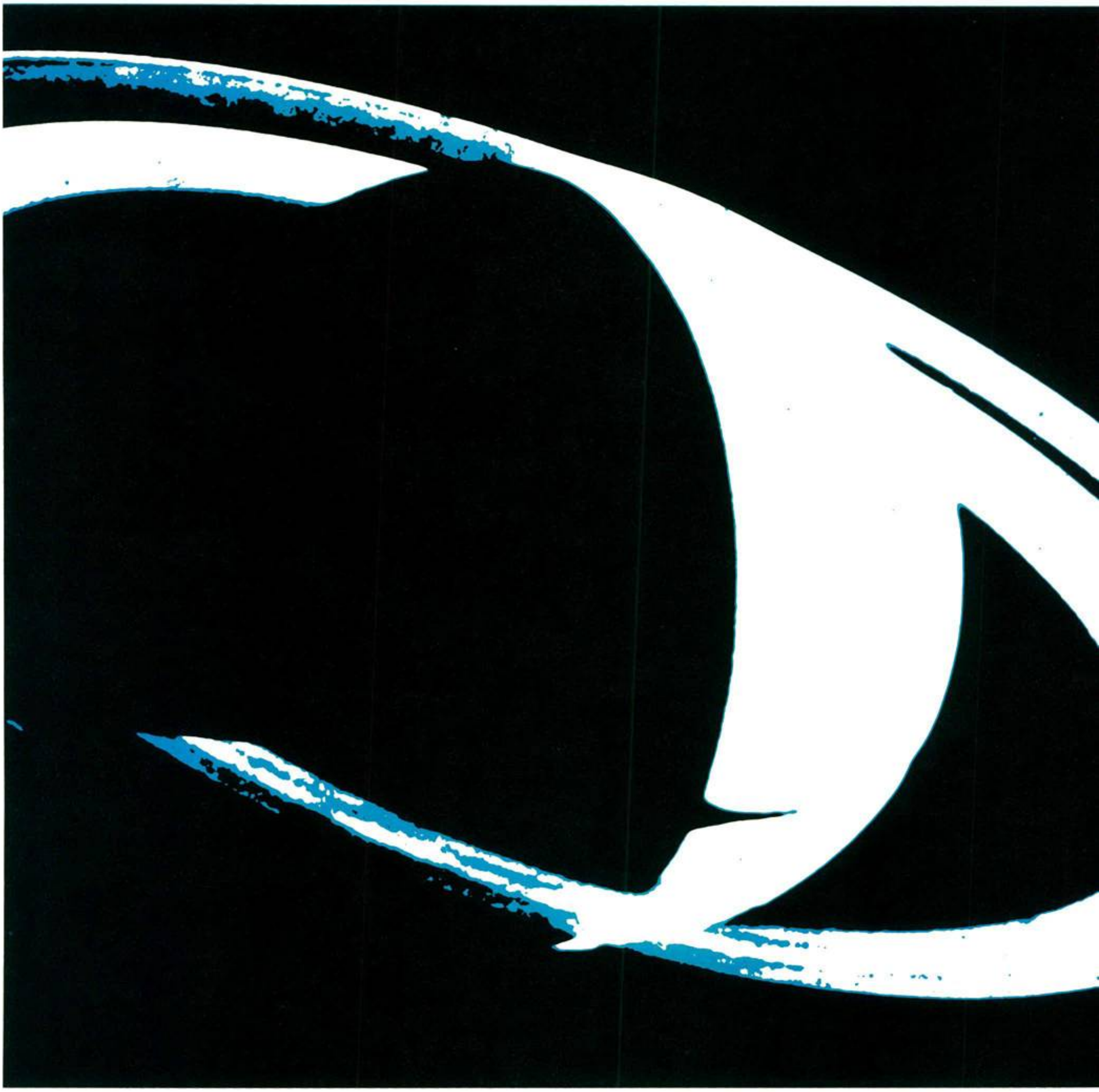
How about radio waves? Their low energy makes them relatively harmless, and a broad range of them passes through our atmosphere. That's encouraging, because the broad range gives us lots of levels of energy to detect. However, there are two problems with having radio eyes. First, the intensities of radio energy are low so that we'd need huge eyes to collect enough photons to see anything but darkness. Second, the wavelengths of radio waves are so long — from tenths of inches to thousands of miles — that in order to see as much detail in scattered radio waves as we see in visible light, we would need huge collectors the size of football fields — which presents a pretty insurmountable problem with logistics of the human body.

That leaves us with infrared radiation, known to



us most basically as heat. Not all infrared radiation gets through our atmosphere. Some of it is reflected by gases in Earth's atmosphere, while some is absorbed by water and carbon dioxide molecules in the air. Fortunately for our survival (and this article), infrared radiation with wavelengths near the red wavelengths of visible light we now see does pass through to Earth's surface. This is called near-infrared radiation. It is also reflected by most things on Earth. Undoubtedly, if Earth creatures had developed infrared eyes, the infrared radiation they would be most sensitive to would be near-infrared. In fact, some snakes have developed infrared vision.

Human anatomy might need some fine tuning to accommodate the infrared-visual world. First, to pick up near-infrared radiation, our eyes would have to be five to ten times larger than they are now. Second, infrared is all around us — in fact it's constantly escaping from our bodies as heat. Because we have internal temperatures of 98.6° F, we give off much more heat than most objects in the world around us. So we've got a physiological problem here. The internal walls in each eye might appear so bright from body heat that they could not detect anything from outside the body. This would be no problem if the eye were surrounded by biological insulation and a biological refrigerant. In



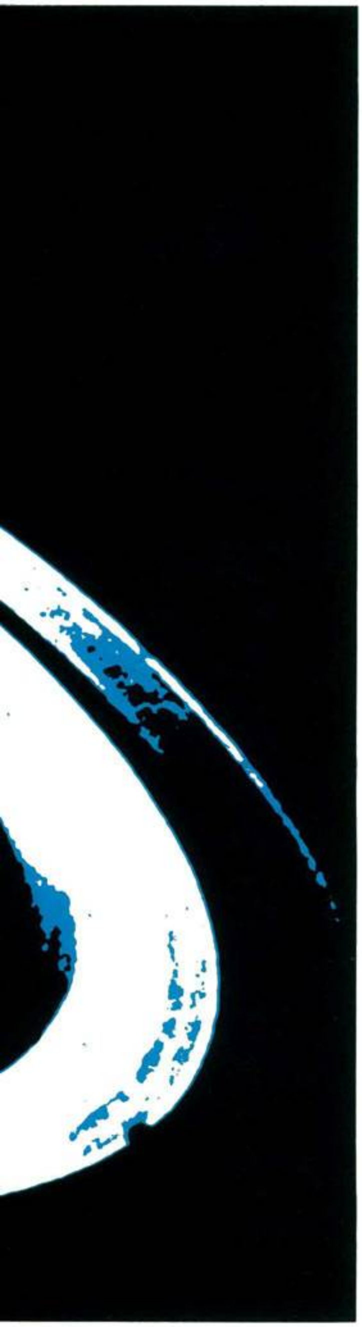
that way, body heat would be drawn away from the eyes, allowing them to detect infrared sources from outside the body. Another way to avoid the heat problem would be eyes extended out on stalks. This might evoke for you the worst of *Star Trek* episodes, but such a design would make infrared detection feasible because the eyes would be air-cooled.

Stalks, refrigerant, whatever. What would we see with our infrared vision? Consider that virtually all visible light we now see comes from sources like the Sun, fires, or electric lights, and is reflected off objects. Visible light that isn't reflected is absorbed and converted into heat, or infrared. For example, an aqua-colored sweater reflects most of the blue and green photons that strike it, while absorbing most of the red, orange, yellow, and purple photons.

How does infrared radiation behave? Pretty much the same way. All objects on Earth both absorb and reflect infrared photons from the Sun during the day. This infrared radiation heats up objects on Earth. The difference between visible and infrared radiation is that during the night, inanimate objects that have absorbed infrared give it off slowly into the cooler surroundings. (That's what prevents everything from freezing after the Sun sets.) How much heat an object can retain and then give off is measured by its so-called heat capacity. Objects with higher heat capacities retain more heat and radiate it away more slowly at night, staying "infrared bright" longer than objects with lower heat capacities.

Another difference is that most of what we see by visible light is by reflection, with the exception of light bulbs, candles, car lights, the Sun, and other emitters. But all living creatures continuously emit their own infrared radiation. Because of this, our infrared eyes would, during

With our infrared eyes we would see a huge network of lacy interstellar gas covering Orion, studded with bright knots of stars coming alive.



the day, see a combination of reflected and emitted light. The hotter an object was, the brighter it would appear to us. And we would be able to see both animate and inanimate objects quite well during the night!

What would the night sky look like if viewed with our infrared eyes? Let's set the vocabulary of our new infrared world. Because the color names we use for visible light objects are familiar, we'll substitute them for different wavelengths of infrared. So we'll call the longest infrared wavelength red and the shortest violet.

Instead of a silvery Moon, we'd have a bluish-white Moon. The Sun would glow bluish-white instead of its familiar yellow. The Moon would be visible much as it is today, in reflected solar energy, but with a strong shift toward blue-white. Jupiter would still have its belts and zones, but would appear slightly brighter than it does in visible light because it internally emits infrared. We would see both the internal light from Jupiter and the scattered glow from the sunlight reflected from it. This is also the case with other gas giant planets with internal heat sources, Saturn and Neptune.

We could also see action in the solar system much more prominently. Whenever objects like asteroids and comets collide, they create observable infrared radiation without necessarily giving off visible light. Imagine that two asteroids grazed each other in a distant corner of the solar system. Our infrared eyes would see a bright burst of light that spreads out and darkens as the debris cools.

Our view of objects outside the solar system would also be significantly changed. The Milky Way contains interstellar gas and dust clouds containing millions of solar masses. The gas is mostly hydrogen, and the dust particles are black grains about the size of those in cigarette smoke. In our visible-light world, this gas and dust obstructs our view of most of the Milky Way by scattering light photons from behind. Now only dust scatters infrared radiation — not gas. And because interstellar clouds are mostly gas, we could see infrared photons from tremendous distances across the Galaxy.

Our night sky would be transformed, both in the numbers of stars we would see and the nature of the starry band of light we call the Milky Way. With our infrared eyes the sky would be aglow with many thousands more stars, including dozens more bright stars. It would give star mappers a much bigger job! We would also see the faint light of the Milky Way — the glow from tens of thousands of distant stars — resembling its appearance in visible light.

We would also see stars come to life with our infrared eyes. Stars form inside thick cocoons of gas which prevent the light from newborn stars from escaping and being visible on Earth. With infrared eyes the cocoons would be glowing brightly through the gas, heated by the photons from the stars inside. Because we could now see stars hidden to visible-light observers, the brightest part of the sky — except for the Milky Way — would lie in the constellation Orion. We would see a huge network of lacy interstellar gas covering most of the constellation, studded with bright knots of stars coming alive.

Perhaps the most striking effect of infrared vision would alter our entire view of the sky, transforming it into a soft canvas on which we would see an apparently painted sky. Rather than seeing stars as sharp pinpoints, we would detect paint strokes of color around most stars as the dust surrounding them scatters large amounts of infrared light toward us. What would the most overwhelming vision an amateur astronomer might get with infrared eyes? — a bright, star-filled sky resembling a great, post-impressionistic canvas stretched over the Earth — a Van Gogh sky! ☐

Neil F. Comins, a professor of physics at the University of Maine in Orono, also wrote "Life Near the Center of the Galaxy," April 1991.

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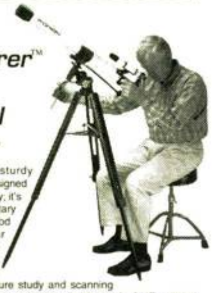

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Open up a new dimension in observation! The stereo effect of this viewer is astonishing. Viewing is more comfortable and it shows more detail, especially of the moon and planets. Specially built for astronomical telescopes, features a fully adjustable 55-75mm interpupillary distance scale and a highly precisce beam splitter which maximizes transmission of light to each eyepiece and equalizes the brightness of each image. Threads securely onto any Celestron or Meade Schmidt-Cassegrain. Includes a thread-on matched 2x Barlow lens. (Shown with two eyepieces, not included.)

#9720 **$399** (3.79)

NEW! Orion® 12.5mm Plössl Illuminated Reticle Eyepiece

This new 12.5mm 4-element Plössl offers unprecidented eye relief and observing comfort during long astrophoto exposures. The battery operated integral illuminator has fully adjustable brightness. Features double crossline reticle.

#8484 **$99** (2.79)

World's Finest Illuminated Reticle Eyepiece

6mm Orthoscopic design for required high-power guiding, plus unique X-Y adjustable reticle positioning for easy guide-star alignment. Wireless LED illuminator has adjustable brightness.

#8487 **$139** (2.79)

Orion® 9mm Orthoscopic Illuminated Reticle Eyepiece

9mm Orthoscopic eyepiece with wireless adjustable brightness illuminator. Bull's-eye within three concentric circles helps measure limits of acceptable guiding error.

#8488 **$119** (2.79)

Orion® 12mm Kellner Illuminated Reticle Eyepiece

12mm Kellner eyepiece with cable plugs into LX/3, LX/5 and Premier drive bases, and most drive correctors with illuminated reticle output for polar alignment and guiding.

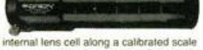
#8482 **$69.95** (2.59)

NEW! Orion® 2" Barlow Lens

2x magnification, Multi-Coated, 2-element 40mm diameter achromatic lens. Baffled to eliminate off-axis glare. Works with all 2" barrel diameter eyepieces. Chrome plated brass barrel and blackened aluminum body with knurled set screw.

#8720 **$69.95** (2.59)

Orion® VariPower™ 2-3x Multi-Coated Barlow Lens



Our best barlow offers significant improvement over other models we've seen. The magnification is adjusted by sliding the internal lens cell along a calibrated scale (you don't have to poke a finger or pencil inside to do this). Fully Multi-Coated optics provide excellent sharpness, contrast and brightness. 1.25" diameter.

#8748 **$69.95** (2.59)

Orion® 3-element Fully Multi-Coated Barlow Lens

Fully Multi-Coated 3-Element Barlow lens provides superior imaging with precise color correction at three wavelengths. For maximum light transmission and highest contrast, we have used the finest quality multi-coating on each air to glass surface. 1.25" diameter.

#8750 **$59.95** (2.59)

Orion® Deluxe Fully-Baffled Multi-Coated Barlow Lens

Fully internally opaqued and baffled to block stray light for noticeably higher contrast. Large 27mm multi-coated 2-element lens provides 2x magnification with any 1.25" eyepiece.

#8746 **$49.95** (2.39)

100% Satisfaction
Money-Back Guarantee

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77° Field UltraScan Wide-Angle Eyepieces

NEW!

Unlimited visibility is yours with up to 77 degrees of field to catch your eye. High quality optical materials and superb coatings, for the ultimate in contrast and resolution.

1.25" UltraScan Eyepieces
Five optical elements utilizing the latest high refractive-index optical glass materials achieve extremely wide fields with fewer elements than many competitive eyepieces, reducing weight and cost. Each lens surface is fully Multi-Coated, for the ultimate in contrast and elimination of stray reflections. Integral rubber eyeguards.

9mm-#8420 **$99** (2.79), *12mm*-#8421 **$109** (2.79)

15mm-#8422 **$129** (2.79), *19mm*-#8423 **$139** (2.79)

2" UltraScan Eyepieces
These incredible oculars provide breathtaking panoramic, bright views that will astonish you!

30mm 2" UltraScan Eyepiece–This 5-element, 77 degree field UltraScan eyepiece combines the widest possible apparent and true fields with a larger image scale than our 40mm.

#8424 **$199** (2.79)

40mm 2" UltraScan Eyepiece - Orion's brightest, widest true-field UltraScan eyepiece utilizes a sophisticated 7-element design, providing a 68 degree apparent field; the widest we could fit into the 2" diameter barrel.

#8425 **$179** (2.79)

High Resolution Orion® Ultrascopic Eyepieces

Unlike other premium eyepieces, Orion Ultrascopics offer complete multi-layer coatings on ALL surfaces, for superior light transmission and contrast. Modern 5- and 7- element designs for pinpoint star images and breathtaking detail. Wide 52° field of view. Compare with other brands selling for much more!

Wide Field 5-element

35mm #8560 **$89.95** (2.59)

30mm #8562 **$79.95** (2.59)

25mm #8564 **$64.95** (2.59)

Medium-High Power 5-element
20mm #8566, 15mm #8568, 10mm #8570, 7.5mm #8572

$59.95 ea. (2.59)

High-Power 7-element 5mm #8574, 3.8mm #8576

$79.95 ea. (2.59)

Orion® MegaVista™ 1.25" Wide Angle Eyepieces

Incredible Fully Multi-Coated high-transmission 7-element eyepieces with integral rubber eyeguard and long eye-relief.

10.5mm- An incredible 67° field for outstanding planetary or deep space performance.

#8552 **$109** (2.79)

16.8mm- Outstanding high-contrast eyepiece with stunning 70° field ideal for deep space.

#8554 **$119** (2.79)

Orion® UltraZoom™ 7-21mm 1.25" Eyepiece

The finest zoom you can buy for your 1.25" telescope. An excellent choice for astronomy or terrestrial observing. 65°-35° field.

#8556 **$129** (2.79)

Orion® Explorer Series 1.25" Eyepieces

Remarkably affordable, Multi-Coated parfocal eyepieces with great performance. Each carefully selected series has been chosen to provide a sensible progression of magnifications. Threaded for filters. Internally blackened to prevent stray light reflections.

Kellner Eyepieces-
6mm #8536, 9mm #8538, 12mm #8540, 18mm #8508, 25mm #8510, 40mm #8512

$33.95 ea. (2.19)

Orthoscopic Eyepieces-5mm #8500, 7mm #8502, 9mm #8504, 12.5mm #8506, 18mm #8524, 25mm #8526

$46.95 ea. (2.19)

Orion® Explorer Series .965" Eyepieces

Get the most from your small telescope with these fine Multi-Coated eyepieces. Standard .965" barrels fit all Japanese standard small telescopes.

.965" Orthoscopic Eyepieces-
5mm #8580, 7mm #8581
9mm #8582, 12.5mm #8583

$37.95 ea. (2.19)

.965" Kellner Eyepieces
18mm #8584, 25mm #8585

.965" Achromatic Huygenian Eyepieces-40mm #8586

$24.95 ea. (2.11)

Orion® SkyGlow™ Enhanced Light Pollution Filters

Enhance your viewing of faint deep sky objects with the best broadband light pollution filter you can buy. Our SkyGlow absorbs frequencies emitted by city lights, allowing transmission of the rest of the visible spectrum, yielding dramatic results.

SkyGlow Broadband Filters- Photographic and Visual
For use in slight to moderately light polluted areas.

1.25" Broadband Filter–fits 1.25" eyepieces.

#5660 **$59.95** (2.59)

Schmidt-Cassegrain Broadband Filter–fits rear cell of Meade & Celestron SC scopes.

#5658 **$79.95** (2.59)

52mm Broadband Filter–For 52mm camera lenses, adapter rings available for other diameters.

#5668 **$66.50** (2.59)

SkyGlow UltraBlock Filters–Visual Only
For severely light polluted areas and faint nebulae.

1.25" UltraBlock Filter– fits 1.25" eyepieces.

#5654 **$79.50** (2.59)

Schmidt-Cassegrain UltraBlock Filter–fits rear cell of Meade & Celestron SC scopes.

#5656 **$99.00** (2.59)

Orion® Color Filters for Eyepieces

Solar system observations are dramatically improved by Orion colored filters. For visual use, thread one into the barrel of any standard eyepiece. For planetary and lunar photography, Schmidt-Cassegrain owners can attach the filter to the eyepiece inside the tele-extender. Can also be threaded directly into a universal camera adapter.

Basic Set of 4 Filters .965"- Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

#5510 **$29.95** (2.19)

Basic Set of 4 Filters 1.25"- Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

#5514 **$39.95** (2.19)

Expansion Set of 4 Filters 1.25"- Includes #21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.

#5516 **$39.95** (2.19)

Deluxe Set of 8 Filters 1.25"- Includes all the filters in our basic and expansion filter sets.

#5517 **$74.95** (2.79)

Individual 1.25" Filters-#80A Blue (#11040), #58 Green (#5540), #25 Red (#5536), #15 Yellow (#5532), #21 Orange (#5534), #47 Violet (#5538), #11 Light Yellow-Green (#5530), #82A Very Pale Blue (#5544)

$11.95 ea. (.99)

Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.

.965" #5664 **$14.95** (2.11)

1.25" #5662 **$14.95** (2.11)

Breakthrough Low-Price Plössl Eyepieces!

NEW!

These new Multi-Coated Plössl eyepieces are incredibly low priced! Good quality optics for sharp, clear images. Precision four-element Plössl lens elements mounted in sturdy aluminum barrels. Available in 12mm, 18mm, or 25mm focal lengths, with 1.25" barrels. Buy all three for less than some single eyepieces!

12mm-#8596
18mm-#8597
25mm-#8598

$39.95 ea. (2.39)

Deluxe Eyepiece Case

Organize and protect your valuable eyepieces and other accessories. This durable case with double hinges holds up to 10 eyepieces plus barlow. Die cut foam insert for snug secure fit. O.D. 8-1/2"x12-1/2"x3-1/8".

#5913 **$17.95** (2.49)

Deluxe Metal-Clad Accessory Cases

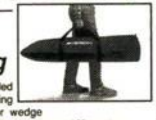
Keep accessories and camera safe and clean. Diced foam inserts can be tailored to your needs. Sturdy handle, two latches, key.

Regular Case: 16"x12"x6 1/2"

#5920 **$49.95** (5.09)

Large Case: 19 1/2"x12"x6 1/2" #5921 **$69.95** (5.92)

Deluxe Field Tripod Tote Bag



Designed for the field tripod with padded insert to separate wedge from tripod during transportation. Specifically made for wedge combinations of Schmidt-Cassegrain telescopes up to 10" aperture. Allows storage without changing polar alignment. This blue bag is made of tear, rip and mildew resistant 100% Cordura nylon.

#15096 **$79.95** (4.65)

Orion FlexiShield™ Dew Caps

NEW!

Eliminate dew problems with FlexiShield! Better performance, more rugged, and easier storage than rigid dew caps. Forms into a tube with the velcro closure, opens flat for easy storage and transportation. Fits your telescope tube snugly, with wide rubber padding and full-length velcro closure—needs no screws. Models to fit most telescopes.

90mm Celestron/Meade Spotting Scopes	#4203	**$24.95**	(2.39)
90mm Celestron Rubber Armored Spotting Scopes	#4205	**$24.95**	(2.39)
4" Meade Schmidt-Cassegrain	#4204	**$24.95**	(2.39)
8" Celestron/Meade Schmidt-Cassegrains	#4200	**$39.95**	(2.39)
10" Meade Schmidt-Cassegrains	#4201	**$49.95**	(2.39)
11" Celestron Schmidt-Cassegrains	#4202	**$59.95**	(2.39)

Orion® Dew Zapper

Orion's Dew Zapper is a sure-fire cure for dew problems on your 8" or 10" Celestron or Meade Schmidt-Cassegrain telescope. Dew Zapper gently replaces lost heat, bringing the corrector plate temperature slightly above air temperature.

8" Dew Zappers-fit all Meade & Celestron 8" Schmidt-Cassegrains

DC Model #3503, AC Model #3504 **$39.95** (2.39)

10" Dew Zappers- fit all Meade 10" Schmidt-Cassegrains

DC Model #3506, AC Model #3508 **$39.95** (2.39)

Dew Remover Gun

Moisture that interferes with viewing dissipates quickly with this 12V DC, 156 watt warm air gun. Has 4-1/2' cord.

#5601 **$17.95** (2.48)

Orion® Slow-Motion Adapter

Attaches to your tripod pan head and gives you two slow-motion control knobs to make precision adjustments in altitude and altazimuth. Very handy for tracking planets, the moon, etc. with refractor teleiscopes and small spotting scopes. Attaches to any camera tripod with a standard 1/4-20 thread.

#7012 **$49.95** (2.59)

Orion® Dual Balance System

Unlike ordinary counter-weights, our system allows instant adjustment in both directions. Easily balances your scope to offset both piggyback loads or rear-cell cameras, 2" diagonals, and other accessories. Rigid, precision machined dovetail bar mounts to telescope in existing accessory holes.

For Meade SC 8"	#5150	**$74.95**	(4.65)
For Celestron 8" C-8	#5149	**$79.95**	(4.65)
For Meade SC 10"	#5152	**$84.95**	(4.65)

Starlite Red LED Flashlight

The Starlite is the only adjustable-brightness night-vision red flashlight. Lifetime solid-state LED can't burn out. Extra efficient electronic circuit for long battery life. Uses one 9-volt battery (not included).

#5714 **$24.95** (2.11)

Astronomer's Flashlight

Indispensable and indestructible. Has special night-vision red filter and a diffusion lens for even illumination. An essential addition to your astronomy accessories. Requires 2 D-cell batteries (not included).

#5701 **$9.95** (1.89)

Rechargeable Battery Porta-Pack

12 Amp Hour Porta Pac
Ideal for operating your telescope plus higher power-consuming accessories such as an Orion Dew Zapper. Battery is encased in high-impact polystyrene. Carrying case of Cordura nylon with shoulder strap and handle. Wt. 10 lbs.

#2354 **$99 ea.** (6.23)

Popular Observer's Chairs

Make observing more comfortable and enjoyable with one of these great chairs.

Standard Model-
Has adjustable-height center column and padded vinyl seat. Folds for easy storage.

#5935 **$39.95** (3.96)

Deluxe Model-
Is much heavier-duty, built for professional- musicians. Extra thick padding, wide footprint. Adjustable and disassembles for storage.

#5934 **$89.95** (5.65)

Orion® UltraGuider

NEW!

Our newest off-axis guider for Celestron and Meade Schmidt-Cassegrain scopes. Easily adjustable prism allows wider choice of guide stars. Precision helical focuser for your guiding eyepiece. Adjustable camera focal plane position. Suitable for advanced deep-space astrophotography. Compare our price!

#5139 **$119** (2.79)

Standard Off-Axis Guider
Name brand quality at a low Orion price! Our popular, precision anodized guider with fully coated prism.

#5144 **$59.95** (2.59)

Rack & Pinion Focusers

NEW!

These top quality focusers are designed for Newtonian reflectors. Fit any size tubes.

1.25" Focuser
Quality diagonal-cut rack for smooth focusing. Secure slide-fit eyepiece holder. Integral socket for single-stalk diagonal support if desired.

#13017 **$44.95** (2.39)

2" & 1.25" Focuser
Large clear diameter ideal for larger scopes and wide-field optics. Precision diagonal cut rack. Long travel for visual and photographic use. Interchangeable 2" and 1.25" holders with set screws.

#13019 **$69.95** (3.31)

Orion® 45-Degree Erect Image Diagonals

NEW!

See the world as it really is with Orion's new 45-degree erect image diagonal. Upside-down, backwards and topsy-turvy images can often confuse even the stoutest and most experienced observer. Turn it right-side-up with your choice of three models to select from.

.965 Diagonal	#8759	**$59.50**	(2.59)
1-1/4" Diagonal	#8753	**$59.50**	(2.59)
Size-Adapting Hybrid Diagonal	#8755	**$59.50**	(2.59)

Star Diagonals

1.25" Star Diagonal
Primarily for astronomical use, lets you view at a right angle. Multi-coated, for 1.25" eyepieces.

#8763 **$39.95** (2.39)

.965" Star Diagonal
Same as 1.25" Star Diagonal, but with standard coated optics. Works with .965" eyepieces and eyepiece holders.

#8761 **$24.95** (1.89)

2" Star Diagonal

Get the widest possible field of view from your Schmidt-Cassegrain Telescope. This star diagonal features a special aluminized and overcoated precision first-surface flat mirror.

#8767 **$89.95** (2.89)

Orion® Tele-Extenders

For high powered photography with your Meade, Celestron 4", 8", 10", 11", 14" Schmidt-Cassegrain.

Standard Tele-Extender
Use this Tele-Extender in conjunction with an eyepiece. Attaches to visual back of Meade or Celestron Schmidt-Cassegrain telescopes, and to 35mm camera with T-ring, sold separately.

#5125 **$27.95** (1.89)

Variable Tele-Extender
Uses an adjustable extension tube, allowing magnification to be changed without switching eyepieces. Attaches with T-ring, sold separately.

#5127 **$39.95** (1.89)

Universal Camera Adapters

Standard Universal Camera Adapters
Combination Eyepiece Projection Tube and Prime Focus Adapter for refractors and reflectors with 1.25" eyepiece holders. Use with T-Ring (sold separately) to match your 35mm camera.

.965" #5268 **$29.95** (1.89)

1.25" #5264 **$34.95** (2.39)

Variable Power Camera Adapter

Unique sliding barrel design allows variable projection distances during eyepiece projection photography, eliminating the need to change eyepieces when magnification changes are required.

#5262 **$44.95** (2.39)

Orion® T-Adapter

For prime focus photography. Use with T-ring to match your 35mm camera. For Meade, Celestron 4", 8", 10", 11", 14" SC. Can be used as 2" camera adapter.

#5116 **$27.95** (1.89)

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IT'S EASY TO ORDER

- Call Toll-Free and charge to your MasterCard or Visa, or send your personal check to order by mail.
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- We ship to U.S. and Canada only.
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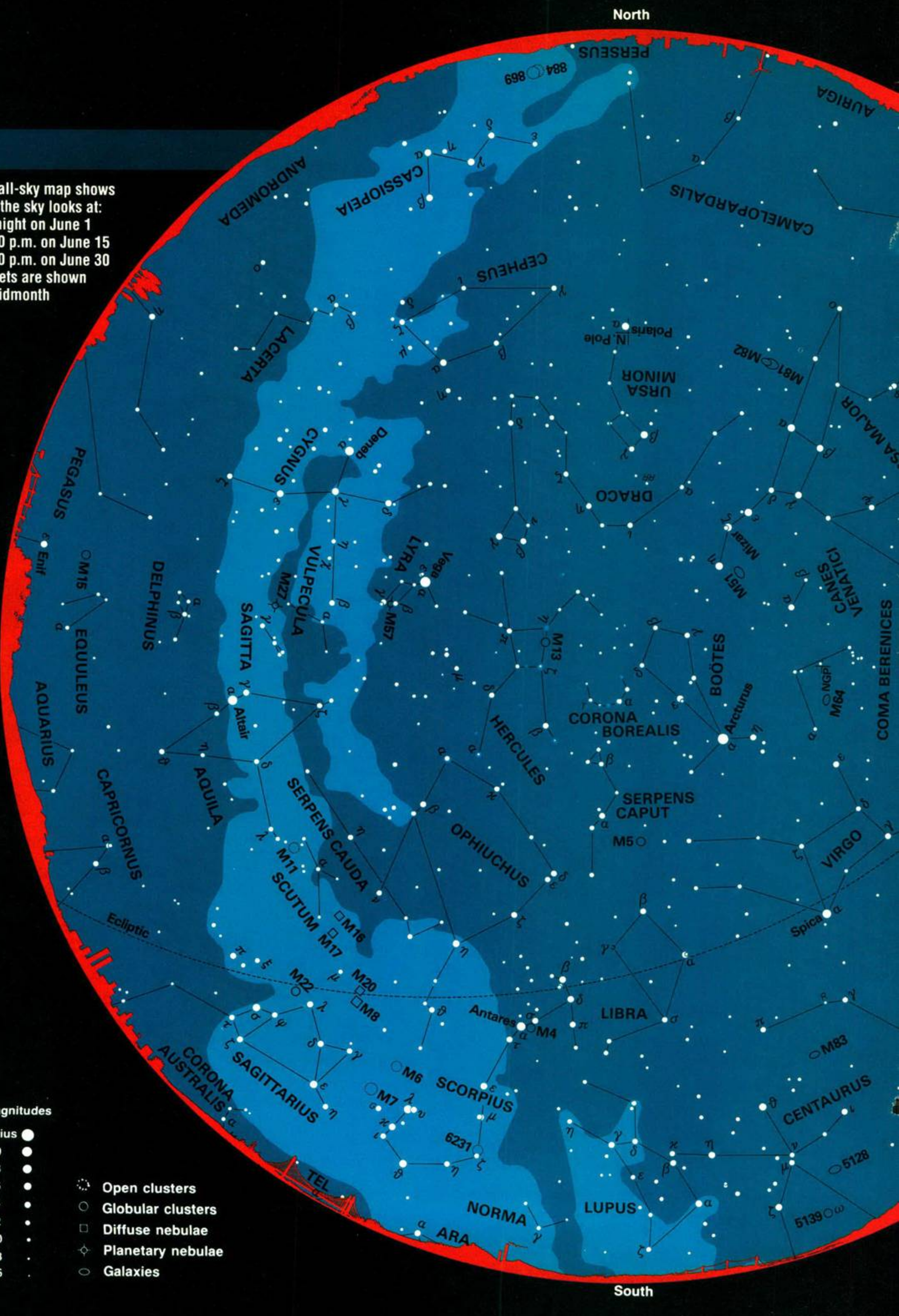
The all-sky map shows
how the sky looks at:
Midnight on June 1
11:00 p.m. on June 15
10:00 p.m. on June 30
Planets are shown
at midmonth


North
South
East
PERSEUS
884
869
AURIGA
CASSIOPEIA
ANDROMEDA
CAMELOPARDALIS
CEPHEUS
LACERTA
Polaris
N. Pole
URSA MINOR
M81
M82
URSA MAJOR
CYGNUS
Deneb
DRACO
PEGASUS
Enif
M15
DELPHINUS
EQUULEUS
VULPECULA
M27
LYRA
Vega
M57
Mizar
M51
CANES VENATICI
SAGITTA
M13
BOÖTES
COMA BERENICES
NGP
M64
AQUARIUS
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AQUILA
HERCULES
CORONA BOREALIS
Arcturus
CAPRICORNUS
SERPENS CAUDA
SERPENS CAPUT
OPHIUCHUS
M5
VIRGO
M11
SCUTUM
M16
M17
Spica
Ecliptic
M22
M20
M8
Antares
M4
LIBRA
CORONA AUSTRALIS
SAGITTARIUS
M6
SCORPIUS
M83
M7
CENTAURUS
6231
5128
TEL
NORMA
LUPUS
5139
ARA

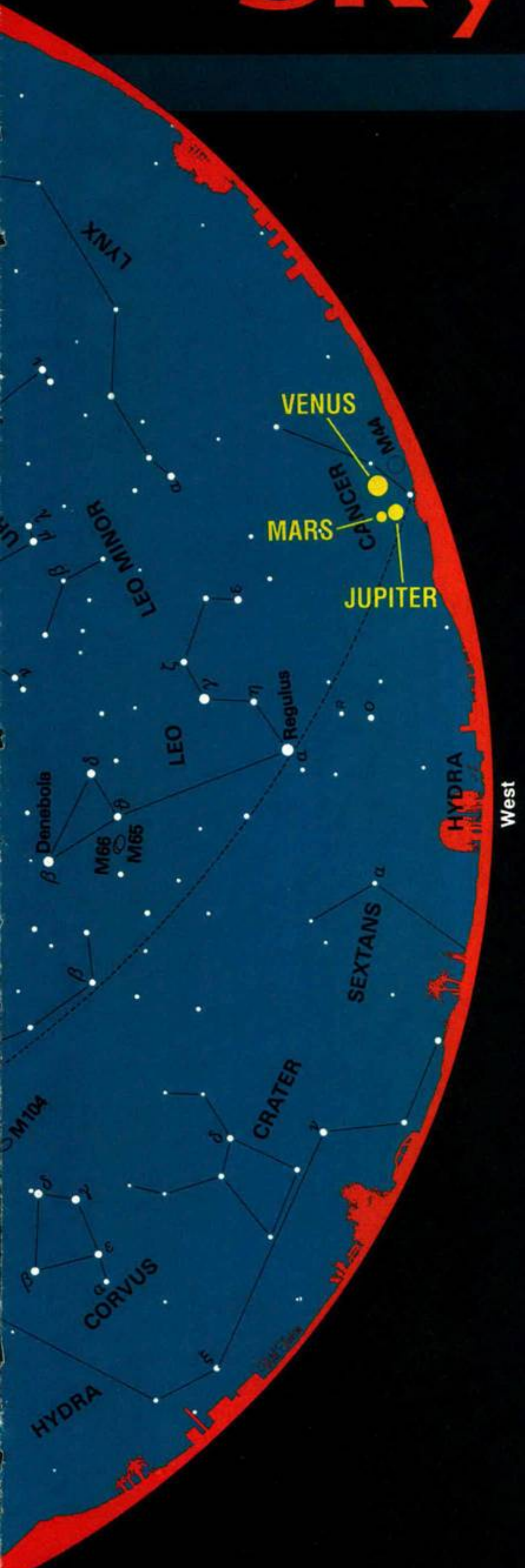
Magnitudes

Sirius ●
0.0 ●
0.8 ●
1.6 ●
2.4 •
3.2 •
4.0 •
4.8 ·
5.6 ·

Open clusters
○ Globular clusters
☐ Diffuse nebulae
Planetary nebulae
⬭ Galaxies

Sky Almanac

June 1991



A STUNNING GATHERING OF PLANETS

All month long the planets Venus, Mars, and Jupiter play tag with one another in the western evening sky. With the naked eye, the most impressive view comes on June 15 when a slender crescent Moon lies nearby. For telescopic observers, the best view is on the 17th when all three planets can be seen in a single field of view.

VENUS AT ITS BEST

Venus reaches greatest elongation on June 13, when it appears farthest from the Sun in our sky. The brilliant planet then lies 45° east of the Sun and sets three hours after the Sun does. Through a telescope, Venus grows dramatically in size during June while its illuminated portion shrinks from a gibbous to a crescent phase.

MARS AND THE BEEHIVE

As the first week of June comes to a close, you can watch the Red Planet slice through the center of the Beehive star cluster. The bright, ruddy planet lies closest to the cluster's hub on the evenings of June 6 and 7, but you can still get a nice view in binoculars or a rich-field telescope on the 5th and 8th.

Calendar of Events

2 The Moon passes 2° north of Saturn, 10 a.m. EDT

5 Last Quarter Moon is at 11:30 a.m. EDT

7 Asteroid Melpomene is at opposition

9 Mars is at aphelion (155 million miles from the Sun)

12 New Moon is at 8:06 a.m. EDT
The Moon is at perigee (222,314 miles from Earth), 8:25 p.m. EDT

13 Venus is at greatest eastern elongation (45°)

14 Mars passes 0.6° north of Jupiter, 1 a.m. EDT

15 The Moon passes 4° south of Venus, 4 p.m. EDT
The Moon passes 3° south of Jupiter, 6 p.m. EDT
The Moon passes 4° south of Mars, 8 p.m. EDT

17 Mercury is in superior conjunction
Venus passes 1.2° north of Jupiter, 7 p.m. EDT

19 First Quarter Moon is at 12:19 a.m. EDT

21 Summer solstice is at 5:19 p.m. EDT

23 Venus passes 0.3° north of Mars, 8 a.m. EDT

26 Full Moon is at 10:58 p.m. EDT; penumbral lunar eclipse

27 The Moon is at apogee (252,428 miles from Earth), 3:23 a.m. EDT

29 The Moon passes 2° north of Saturn, 2 p.m. EDT

30 Mercury passes 5° south of Pollux, 6 p.m. EDT

A TWILIGHT GATHERING OF PLANETS

Three planets stage a dramatic meeting this month in the western twilight sky. These three — Jupiter, Mars, and Venus — have been drawing closer to one another over the past several weeks. This month they are exceedingly close together. They are closest on June 17, when they fit inside a circle only 1.8° across.

Venus is the brightest of the three and the first to pop into view after sunset. It shines at magnitude –4.3, ten times brighter than Jupiter, which shines at magnitude –1.8. At magnitude 1.7, Mars is some 25 times fainter than Jupiter and 250 times fainter than Venus. It appears as a relatively inconspicuous ruddy dot.

You can easily track the relative motions of these planets by noting their changing positions throughout the entire month. When June begins, they lie along a straight line in the western sky after sunset. This line marks the whereabouts of the ecliptic — the apparent path followed by the Sun, Moon, and planets.

By midmonth, the planets are clustered together in a tight grouping in the twilight sky. Many of your friends will probably glance up around this time, notice the planets, and wonder what they might be. As you help acquaint them with the sky, be sure to mention that on the evening of June 15, a thin crescent Moon will appear spectacularly near the planets. That night you can use the Moon as a guide to finding Venus and Jupiter before the sky begins to darken.

Also be sure to aim your binoculars toward these planets when they are closest together. They all fit easily in a single field of view, which affords you the chance to compare their colors. Mars has a distinct orange-red hue, while Venus is a brilliant white and Jupiter slightly cream-colored.

VENUS LIES FARTHEST FROM THE SUN

The great gathering of planets couldn't be timed better, because Venus reaches its maximum apparent distance from the Sun, or greatest elongation, on June 13. It then lies 45° east of the Sun and appears midway up in the west at sunset. Because they are relatively high in the west when the Sun goes down, Venus, Jupiter, and Mars can be seen for a full three hours after sunset.

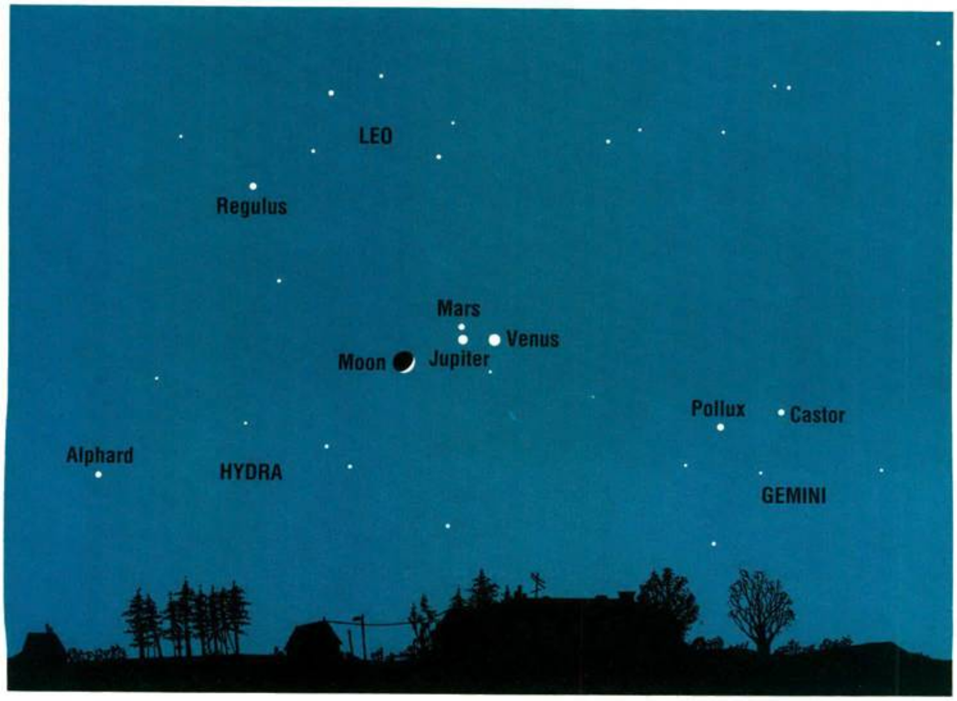
Although Venus is farthest from the Sun this month, it is not as high in the sky as it was last month. The reason is that the ecliptic is now less upright relative to the horizon than it was just a month ago.

If you train your binoculars on Venus, you may notice that the planet appears slightly out of round. The reason becomes clear if you view Venus through a telescope — the planet appears only half-lit, like the Moon at First or Last Quarter.

THE ONSET OF SUMMER

On June 21, the Sun reaches its most northerly point in the sky. This is the June solstice, an

A QUARTET OF BRIGHT OBJECTS in the twilight sky makes for a stunning sight on the evening of June 15. Look low in the west to see the slim crescent Moon lying near the planets Venus, Mars, and Jupiter.



event that marks the beginning of summer in the Northern Hemisphere and the beginning of winter in the Southern Hemisphere. It also brings with it the most hours of daylight to the Northern Hemisphere. If you watch where the Sun rises or sets for a few weeks around the solstice, you'll see that its rising or setting point is farthest north along the horizon at the solstice.

JUNE'S PLANETS

Venus shines brilliantly in the west after sunset. It is not only the brightest of the three planets that cluster in that part of the sky this month, but also the brightest point of light in the sky. Be sure to look for Venus on June 17, when it passes 1.2° north of Jupiter, and on June 23, when it lies 0.3° north of Mars.

Jupiter is the second-brightest of the three planets in the western twilight sky. When the month begins, it is also the highest of the three, 13° to the upper left of Venus. By the end of the month, however, it is the lowest of the three, some 8.5° to the lower right of Venus. If you view Jupiter with a pair of binoculars, look for some starry specks of light near the planet. These are its largest and brightest moons, the famed Galilean satellites of Jupiter.

Mars is the faintest of the three planets in the west after sunset. Both it and Jupiter are now far across the solar system from Earth and are about to drop into the Sun's glare. Jupiter appears much brighter than Mars because it is so much larger and thus reflects more sunlight back in our direction. In addition to Mars' conjunction with Venus on June 23, look for the Red Planet as it passes 0.6° north of Jupiter on the evening of June 13.

With a pair of binoculars, you can watch Mars pass in front of one of the largest and brightest star clusters in the sky. This is the Beehive star cluster, also known as Praesepe, in the constellation Cancer. The Beehive has a total magnitude of 3.1 and measures a whopping 95' across, about three times the size of the Full Moon. Mars appears most directly between us and the Beehive on the evenings of June 6 and 7.

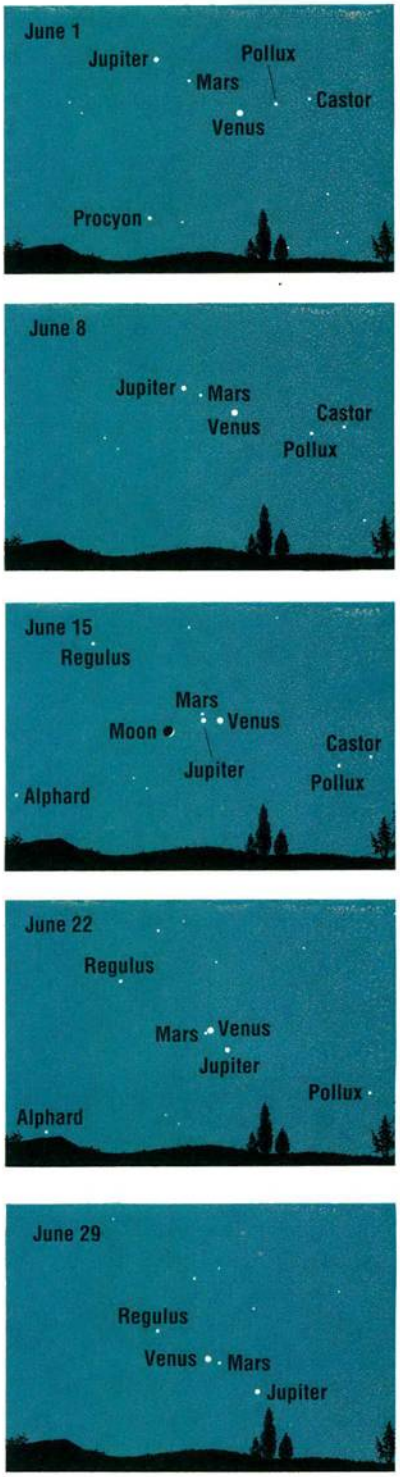
With so much activity going on in the evening sky this month, you might be tempted to pass over the objects in the morning sky. That would be a mistake, however, because Saturn is now nearly at its best for the year. When the month begins, the ringed planet rises in the east-southeast around midnight. It can be seen best in the south before dawn, a glowing 0.4-magnitude point of light in the constellation Capricornus. By the end of June, Saturn rises at the end of evening twilight.

Saturn will reach opposition in late July. Even though the planet will be a bit closer to us this year than last, it won't be quite as bright. That's because Saturn's rings contribute greatly to the planet's overall brightness, and this year they appear less open from our perspective. The rings will continue to close until 1995, when they'll appear edge-on, and won't appear as open as they do this year again until 1999.

Mercury is lost in the Sun's glare for most of June. It is on the far side of the Sun, in superior conjunction, on June 16/17. You can see Mercury very low in the east-northeast before sunrise at the beginning of the month, but it is easier to spot in the west-northwest after sunset at the end of the month. Look 20° to the lower right of Jupiter about 30 minutes after sunset.

THE STARRY SKY

This month one of the greatest figures in celestial mythology ascends in the east during the evening hours. It is the constellation Hercules, the legendary strongman of the sky, whose Twelve Labors helped populate the heavens.



THE PATTERN OF PLANETS in the western evening sky changes constantly during June as Venus, Mars, and Jupiter all pass one another.

Hercules is one of the most ancient constellations. Although our primary legends about it come from Greek mythology, it's unlikely that the Greeks identified this pattern of stars with the well-known myths. Instead, they may have seen an unknown kneeling figure here, which only later became identified with the great hero of Greek mythology.

And hero he was! The adventures of Hercules are some of the most famous in Greek mythology. His father was the god Zeus and his mother a mortal, the princess Alcmene. Zeus' wife, Hera, was jealous of Hercules, despite the fact that Zeus had named the child "Heracles," meaning "The Glory of Hera," just for her. Hercules' adventures began when Hera sent two serpents to his cradle to kill him. Mighty Hercules, the world's strongest baby, strangled the snakes with his bare hands.

Yet his greatest feats came later — the famous Twelve Labors of Hercules. The first labor was to kill the Nemean Lion, which later became the constellation Leo. His next task was to kill Hydra, a many-headed monster and another figure that has given its name to a constellation. In fact, all of the Twelve Labors are supposed to have astronomical significance. It's said that they refer to the Sun's passage through the twelve constellations of the Zodiac.

Hercules is the fifth-largest constellation in the sky but is also rather dim, with its brightest stars glowing only at 3rd magnitude. You can nevertheless spot it fairly easily by using the surrounding constellations. Hercules lies just east of a bright semi-circle of stars, the constellation Corona Borealis. And the mighty hero is located just west of the bright star Vega in the small, distinct constellation Lyra.

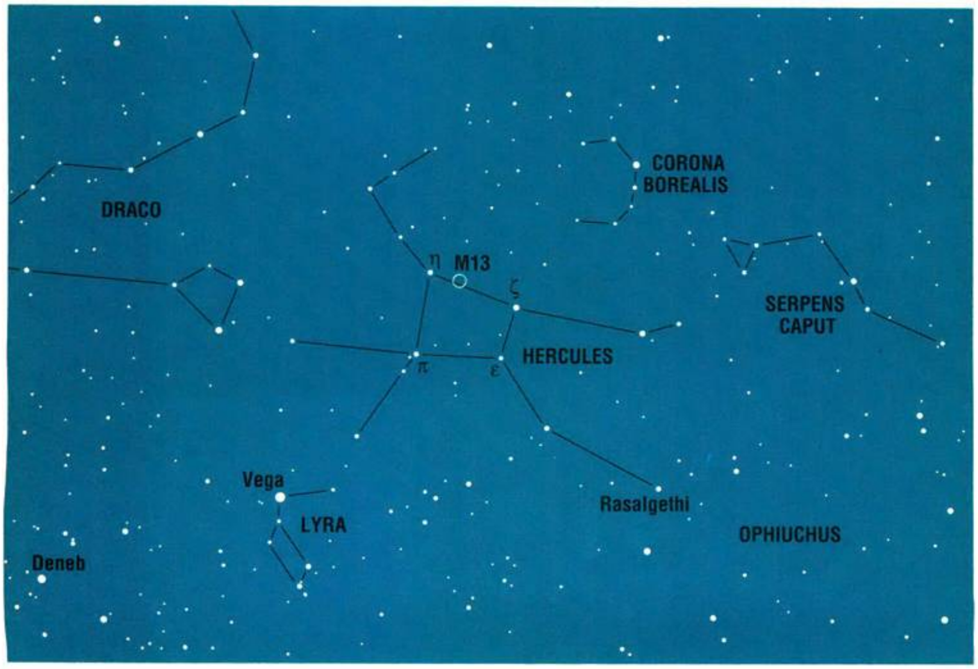
With the aid of a dark sky and your imagination, you might be able to see Hercules as a kneeling man. The reddish star Rasalgethi marks the giant's head. The constellation also contains a famous asterism called the Keystone. This awkward square of stars is formed by the stars Eta (η), Zeta (ζ), Epsilon (ε), and Pi (π).

Conveniently situated within the Keystone is a great globular cluster of stars. The cluster is commonly known as M13, because it was thirteenth in a list of non-comets, or "objects to avoid," compiled by Charles Messier. M13 was apparently discovered by Edmond Halley, of Halley's Comet fame, in 1714. Halley's Nebula was one of its early designations.

At magnitude 5.9, M13 is visible to the naked eye under a dark sky. One of more than a hundred globular clusters that orbit the center of the Milky Way Galaxy, it is the best example of such a cluster in the northern sky.

M13 lies about 25,000 light-years from Earth and spans more than 150 light-years in diameter. To see it, look about $^1/_3$ of the way from the star Eta to Zeta in the Keystone. Spotting it with the naked eye is challenging, but it's an easy binocular target. And once you know that this fuzzy spot is actually a collection of hundreds of thousands of stars located halfway across the Galaxy, it is truly an awe-inspiring sight. ☐

Deborah Byrd is the creator, writer, and producer of "Star Date," an independently syndicated daily radio series on commercial and public radio.



HERCULES THE HERO is marked by its distinctive Keystone asterism and features the famous globular cluster M13. You can find Hercules high in the eastern sky late on June evenings.

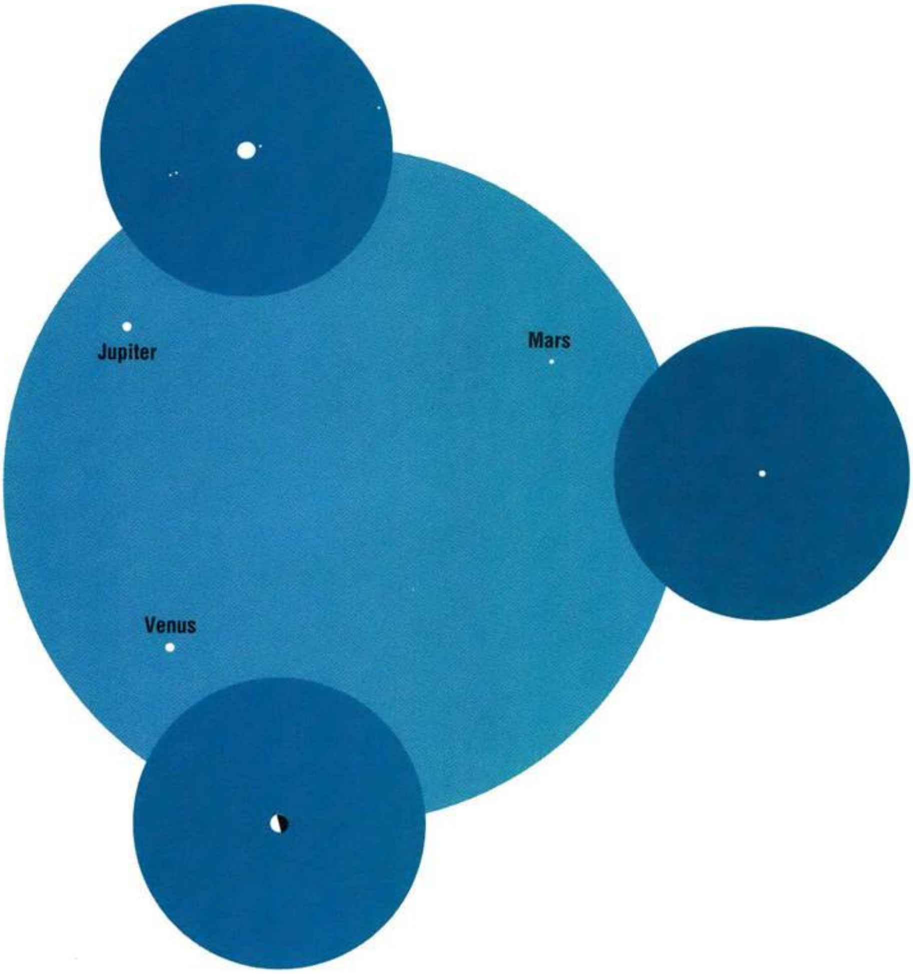
Through the Eyepiece *by* Rick Shaffer

THE DANCE OF THE PLANETS

For several months running, we've been entertained by the series of mutual events among Jupiter's Galilean satellites, and June will be no exception. In fact, this month it seems almost as though the mutual events have become contagious, because we have three exquisite planetary "mutual events," or conjunctions, to view. Center stage is the western evening sky, and the featured players are Venus, Mars, and Jupiter.

The first conjunction occurs on June 14, when Mars passes 0.6° north of Jupiter. Although the two share the same right ascension shortly after midnight eastern time, they move a bit closer to each other around midday. For observers in the Americas, the view should be equally good on the evenings of the 13th and 14th, while observers in the Eastern Hemisphere get their best view on the 14th.

Wherever you happen to live, you can easily fit both planets into a single eyepiece field. Start with a low-power eyepiece — this will show the planets' colors most vividly. Contrast the ruddy hues of Mars with the cream-colored zones and the brown to brownish-red belts of Jupiter's cloudtops.



VENUS, MARS, AND JUPITER all fit into a low-power, 2°-wide field of view on the evening of June 17, but you'll have to magnify the individual planets considerably to see any details. South is at top to match view in a telescope.

Once you've examined the colors of the two planets, boost the power as much as you can while keeping the planets in the same field. (If you have a set of wide-field eyepieces, you should be able to go as high as 90x.) With the higher magnification the planets appear larger, and you have a better chance of seeing disk features. Consider yourself lucky if you see much of anything on the tiny, 4.3"-diameter disk of Mars. On the other hand, you should have little problem seeing a wealth of detail on the 33.1"-diameter disk of Jupiter.

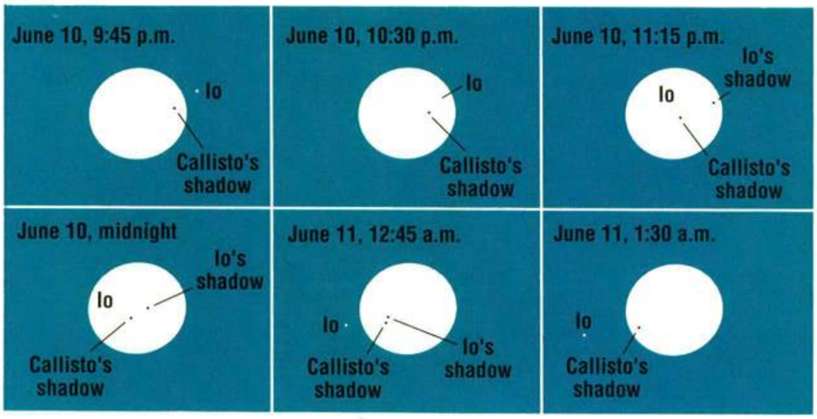
As you contrast the colors and apparent sizes of Mars and Jupiter, consider the real differences between the planets as well. Mars is a small, rocky world just 6,800 kilometers in diameter. Jupiter, the world seemingly right next to it, is 21 times the diameter of Mars. The giant planet is composed mostly of gas and liquid and has only a small rocky core.

As Mars and Jupiter drift slowly apart after their conjunction, Venus approaches the pair. The three are closest during the day on June 18, but the best view from North America comes on the evening of the 17th, when they all lie within 1.8° of each other and can be seen together in a low-power eyepiece. Don't expect to see much more than points of light at this magnification, however. To see any detail on the individual planets, you'll have to up the power substantially.

On the very same night, the second of June's planetary conjunctions takes place. Venus passes 1.2° north of Jupiter at 7 p.m. EDT on the 17th. It's a perfect opportunity to marvel at the contrast between the dazzling-white of Venus and the more muted tones of Jupiter.

Under higher magnification, you can see that Venus' 24.7"-diameter disk is just under half-lit, while the Jovian disk measures 32.8" across and appears full. Although all we see when we look at Venus and Jupiter are the tops of their cloud layers, the similarity between the two worlds ends there. Venus is a rocky planet that measures approximately 12,100 kilometers in diameter, while Jupiter is a dozen times larger.

After each of their conjunctions with Jupiter, Venus and Mars have one of their own. During the morning hours of June 23, Venus passes 0.3° north of Mars. That means the evenings of June 22 and 23 are the best times to view the pair from North America. The pure white of Venus stands in sharp contrast to ruddy Mars and its dark gray-green markings. Because this is the closest of the three conjunctions, you'll be able to use a much higher power and still keep the planets in the same field of view.



WATCH IO AND ITS SHADOW slide across Jupiter's disk on the night of June 10/11 while Callisto's shadow plods slowly along (above; times are eastern daylight). This is just one of many phenomena of the Galilean satellites that can be seen throughout June.

GALILEAN SATELLITE PHENOMENA

Date	Event	Time
	IO	
June 3	Occultation begins	2h57m
	Eclipse ends	6h20m
June 11	Transit begins	2h05m
	Shadow enters	3h05m
	Transit ends	4h23m
	Shadow leaves	5h22m
June 18	Transit begins	4h05m
	Shadow enters	5h00m
	Transit ends	6h23m
	Shadow leaves	7h17m
June 19	Occultation begins	1h26m
	Eclipse ends	4h38m
	EUROPA	
June 15	Occultation begins	4h12m
	Eclipse ends	9h02m
June 24	Transit begins	2h08m
	Shadow enters	3h48m
	Transit ends	5h00m
	Shadow leaves	6h39m
	GANYMEDE	
June 1-2	Occultation begins	23h08m
	Occultation ends	2h46m
	Eclipse begins	3h33m
	Eclipse ends	7h13m
June 27	Transit begins	2h07m
	Shadow enters	5h21m
	Transit ends	5h45m
	Shadow leaves	8h59m

Times are given in universal time. Subtract 4 hours to convert to EDT, 5 hours for CDT, 6 hours for MDT, and 7 hours for PDT.

JUPITER'S PRIVATE DANCE

The giant planet's four Galilean satellites continue their series of mutual eclipses and occultations this month. For a summary of the first few months of this series and a preview of what lies ahead, see "The Dance of the Jovian Moons" on page 76.

In addition to the mutual events, the Galilean satellites have many events with Jupiter itself. Now that Jupiter is past opposition, when a moon passes in front of the planet, its disk can be seen traversing the Jovian disk followed by the moon's shadow. When a moon passes behind the planet, it first disappears behind Jupiter and is then eclipsed in Jupiter's shadow. The best event for North American observers this month is the one on the night of June 10/11. As Callisto's shadow moves slowly across the face of the planet between 1h09m and 5h55m UT on the 11th (subtract 4 hours to convert to EDT, 7 hours to convert to PDT), both Io and its shadow speed across the Jovian disk. The disk of Io transits from 2h05m to 4h23m UT, while Io's shadow follows close behind, crossing from 3h05m to 5h22m UT. See the table at left for the times of other Jovian satellite phenomena.

A PROMISE OF THINGS TO COME

The night of June 26/27 brings with it a fine chance to test your observing skills: a slight penumbral lunar eclipse. Observers in the eastern half of North America, all of South America, and western Africa can see the entire eclipse, while those in western North America see the Moon rise during the eclipse and those in Europe and eastern Africa see the Moon set during the eclipse. The Moon passes through the outer part of Earth's penumbra during this eclipse, and at maximum only 34 percent of the Moon's surface is in the shadow. You'll need a sharp eye to detect any dimming of the Moon at all.

Although this eclipse is pretty minor, it is a harbinger of better things to come. Because the Moon passes through the edge of Earth's shadow, Earth will pass through the very center of the Moon's shadow half a lunar month from now. Thus, on July 11 we'll have an extraordinary solar eclipse. Boasting nearly seven minutes of totality at maximum, this will be the longest total eclipse of the decade! (For more eclipse details, see "Travel Tips for the Big Eclipse" on page 68.)

TELESCOPIC PLANETS

Mercury is difficult to spot all month. It lies low in the east-northeast before sunrise during the first week of the month, swings behind the Sun at mid-month, and ends the month low in the west-northwest after sunset. On the 1st, the innermost planet measures 5.8" across and is 76-percent lit. On the 30th, it measures 5.4" across and is 85-percent lit. Its one saving grace is that it shines brighter than magnitude –0.5 all month.

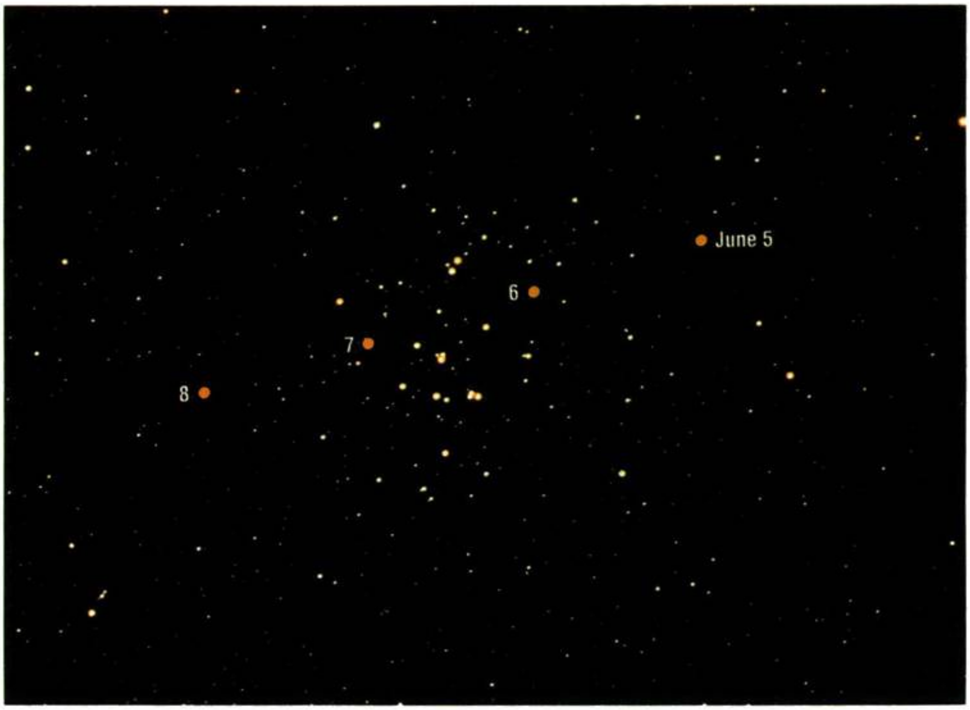
There's much more to observing Venus this month than seeing its close conjunctions with Mars and Jupiter. Our neighbor reaches its greatest elongation east of the Sun on June 13, so we're entering the period during which its telescopic appearance changes rapidly. On the 1st, Venus shines at magnitude –4.2 and displays a 20.6"-diameter disk that is 56-percent illuminated. By the 30th, the planet has brightened to magnitude –4.4 and its 28.9"-diameter disk is 40-percent lit.

The Red Planet also has more to offer this month than planetary conjunctions. At the end of the first week of June, Mars passes right through the heart of the Beehive star cluster, M44. Mars appears closest to the cluster's center on the evenings of June 6 and 7, but it still makes for a fine telescopic sight on the 5th and 8th. Although Mars pales in comparison to the much brighter planets in its vicinity, it easily outshines the much fainter stars in the Beehive.

Saturn now rises before midnight and is high in the south as morning twilight begins. The ringed planet will reach opposition late next month. Because Saturn has a low declination (–19°), it doesn't climb out of the horizon murk until a few hours before twilight begins. The 0.4-magnitude planet measures 18.0" across, while its glorious ring system spans 41.0".

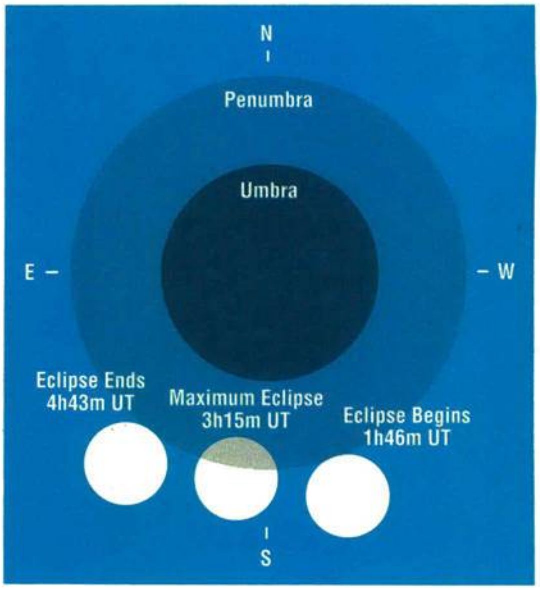
A personal note: I've been writing this column for three years now. It has certainly been a rewarding experience, but it has also taken a considerable amount of time. In recent months, my duties on the Ulysses project have left me less and less spare time. To alleviate this problem, Jeff Kanipe — former associate editor at ASTRONOMY and now editor of *Stardate* magazine — will write this column in odd-numbered months and I will continue to write it in even-numbered months. I cannot help but believe that Through the Eyepiece and its readers will benefit from this arrangement. One final note: The finished product you see every month is the result of the very capable editing job done by Rich Talcott. Every writer should have an editor as good as he. ☐

Rick Shaffer is a technical group leader at the Jet Propulsion Laboratory in Pasadena, California. He leads the data management team on the Ulysses mission, a spacecraft on its way to Jupiter and the Sun.

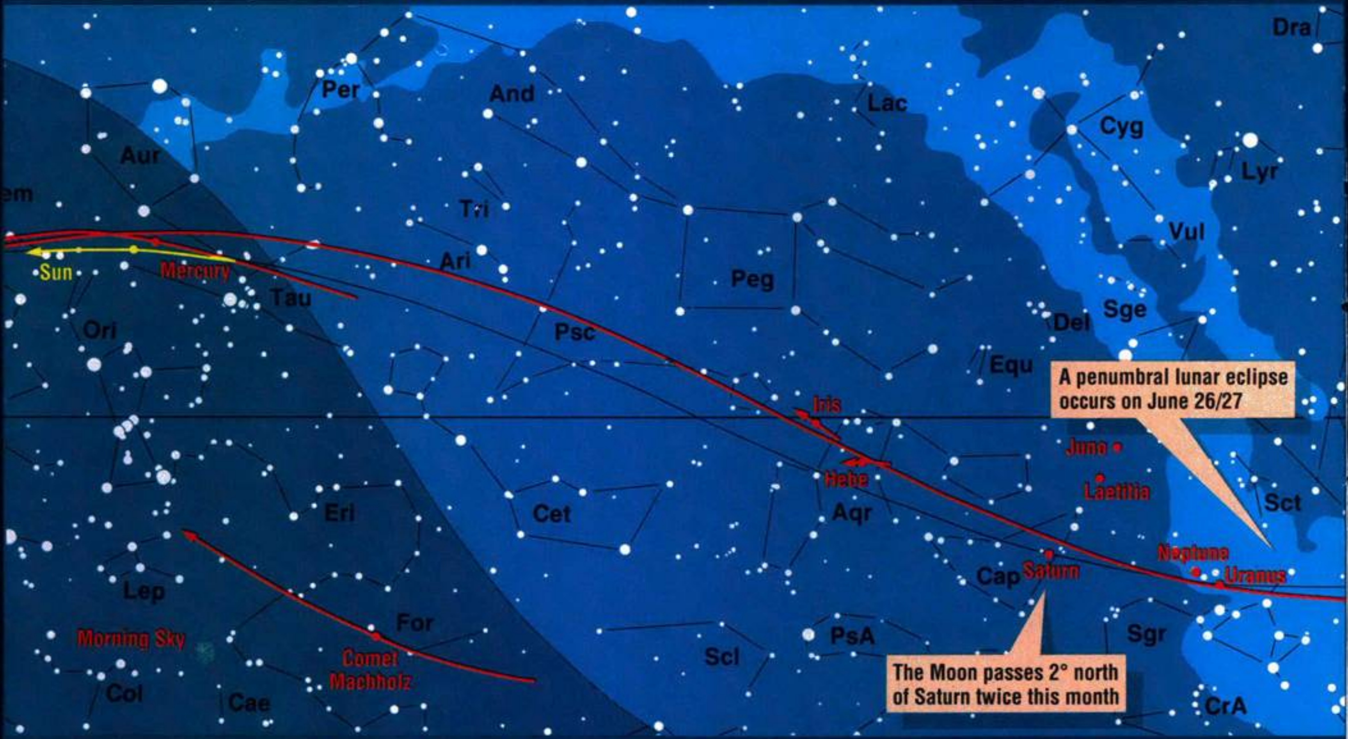


MARS CUTS THROUGH THE HEART of the Beehive star cluster at the end of the first week of June. Photo of M44 by Mace Hooley.

A PENUMBRAL LUNAR ECLIPSE darkens the Moon slightly on the night of June 26/27 for observers in North and South America, Europe, and Africa. (All times are in UT; subtract 4 hours to convert to EDT, 7 hours for PDT.)



The Solar System June 1991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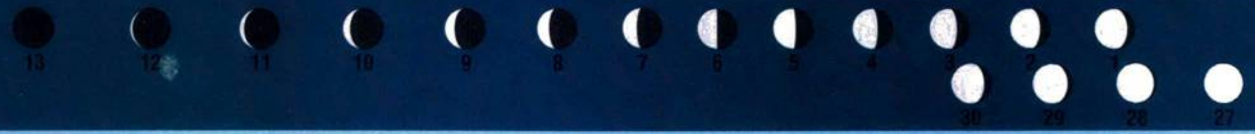
A penumbral lunar eclipse occurs on June 26/27

The Moon passes 2° north of Saturn twice this month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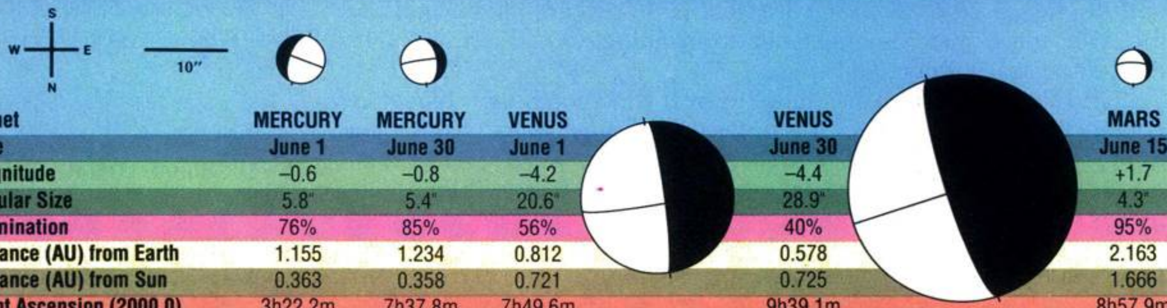
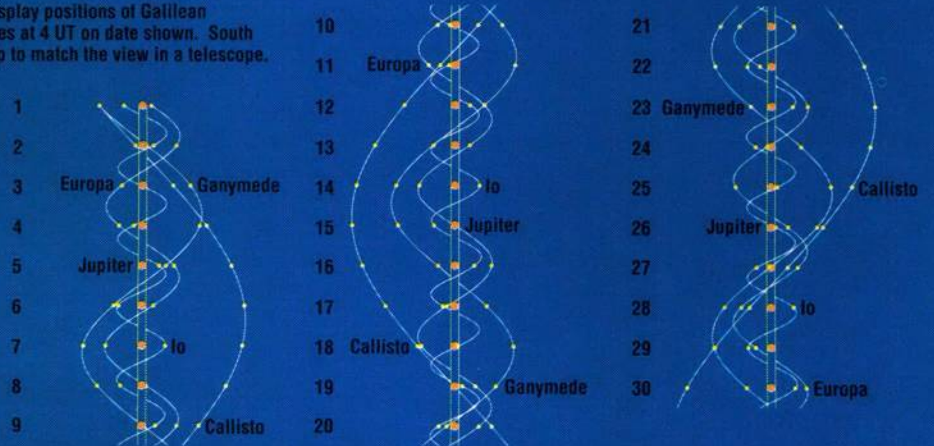
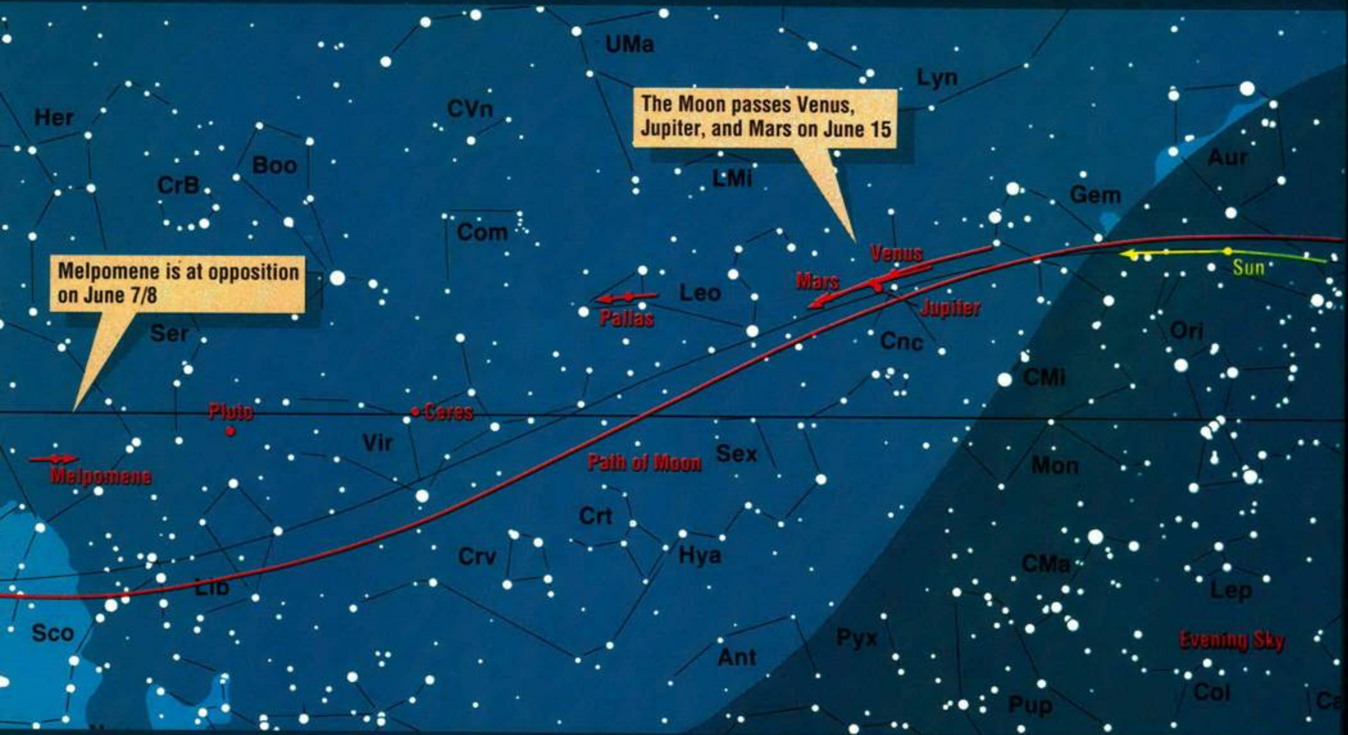


Planet	MERCURY	MERCURY	VENUS	VENUS	MARS
Date	June 1	June 30	June 1	June 30	June 15
Magnitude	–0.6	–0.8	–4.2	–4.4	+1.7
Angular Size	5.8″	5.4″	20.6″	28.9″	4.3″
Illumination	76%	85%	56%	40%	95%
Distance (AU) from Earth	1.155	1.234	0.812	0.578	2.163
Distance (AU) from Sun	0.363	0.358	0.721	0.725	1.666
Right Ascension (2000.0)	3h22.2m	7h37.8m	7h49.6m	9h39.1m	8h57.9m
Declination (2000.0)	16°40′	23°29′	23°41′	15°02′	18°35′

Jupiter's Moons

Dots display positions of Galilean satellites at 4 UT on date shown. South is at top to match the view in a telescope.

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Ceres
Vir
Path of Moon
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Melpomene
Crt
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Hya
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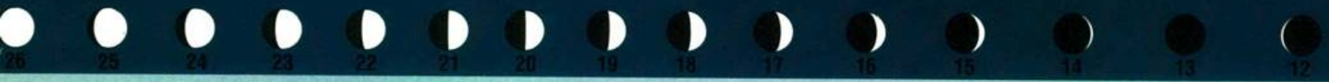
Pup

The Moon passes Venus, Jupiter, and Mars on June 15

Melpomene is at opposition on June 7/8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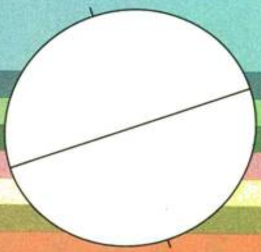
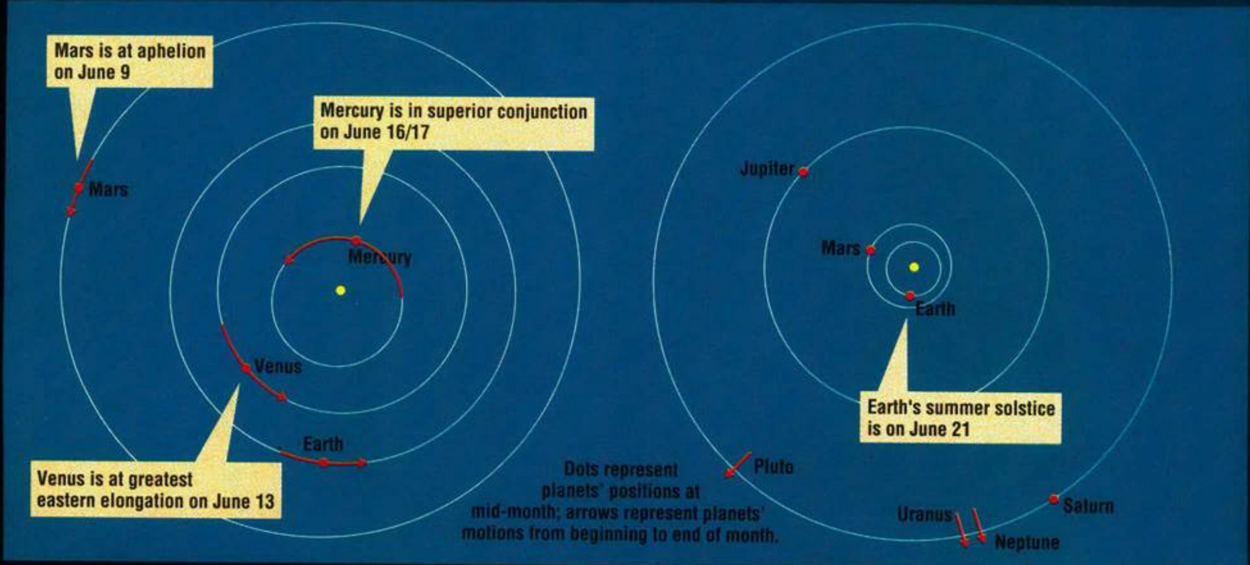


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
June 15	June 15	June 15	June 15	June 15
−1.8	+0.4	+5.6	+7.9	+13.7
33.0"	18.0"	3.8"	2.3"	0.1"
99%	100%	100%	100%	100%
5.962	9.199	18.512	29.258	28.870
5.335	9.968	19.474	30.199	29.674
8h56.6m	20h35.2m	18h55.4m	19h09.4m	15h19.9m
18°03'	−19°05'	−23°13'	−21°40'	−2°18'

The Planets in Their Orbits


Mars
Mercury
Venus
Earth
Jupiter
Mars
Earth
Pluto
Uranus
Saturn
Neptune

Mars is at aphelion on June 9

Mercury is in superior conjunction on June 16/17

Venus is at greatest eastern elongation on June 13

Earth's summer solstice is on June 21

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

Travel Tips for the Big Eclipse

Are you travelling in search of the Moon's shadow next month? Here's a collection of valuable tips to make your journey to totality more enjoyable.

By Joel K. Harris

It's hot. So hot that you aren't sure you can find any relief from the Sun beating down on you. But within a few minutes, the sky darkens into an eerie night, and a breeze comes up and brushes against you. You look skyward, and you see Jupiter, Venus, Sirius, and the stars of Orion, all surrounding what looks like a black hole in the heavens.

The foregoing is not some dream sequence from a Brian DePalma movie. Instead, you are in the state of Baja California Sur, Mexico. The time is 11:48 a.m. on July 11, 1991. You are awash in the lunar umbra, or shadow, and you're witnessing the longest total solar eclipse for the next 140 years.

If you plan to be in the Moon's shadow on July 11, either in Baja or at a site in another part of Mexico, you'll need to know some important travel information. If you head south unprepared, your journey of a lifetime might become the dreaded "vacation from hell."

By now you should have already made your plans for travelling to the eclipse of the decade, whether it be on your own or with an organized tour. A previous article, "A Journey into Darkness," in the July 1990 issue, gave prospective eclipse chasers information on where to go for the eclipse and tours that would take them there.

Perhaps following the advice in the earlier article, you've made flight and hotel bookings. No? Well, if you haven't and are only now thinking of heading to the eclipse, this collection of travel tips will help make your journey a safe one. But be warned — hotels are booked solid in southern Baja, the prime site for viewing the total eclipse. And there will be travel restrictions in force that will make it very difficult for last-minute tourists to "crash" the Baja eclipse party.

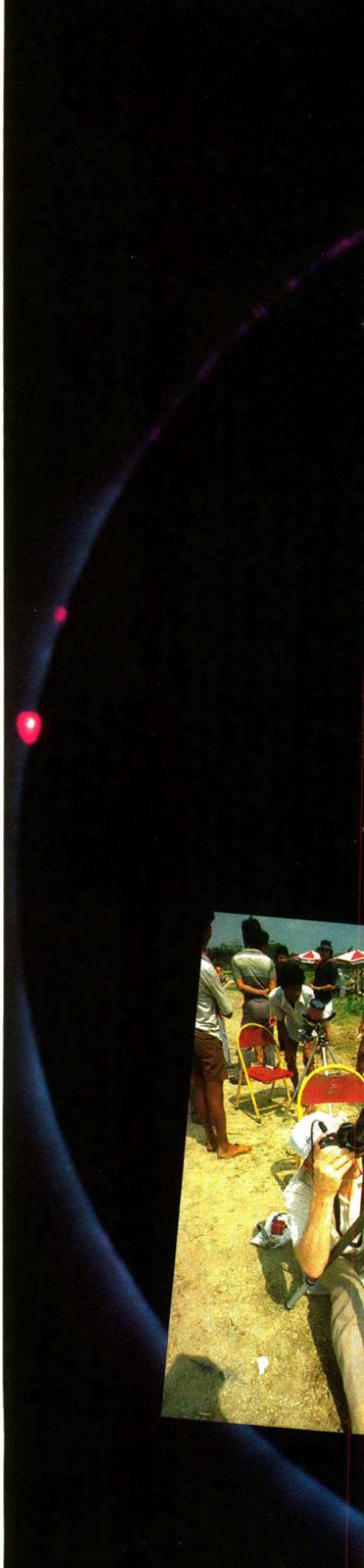
The Long and Winding Road

The most compelling reason skywatchers are flocking to the southern tip of Baja for this eclipse is the length of the eclipse from there (nearly 7 minutes). Baja is also close to the U. S. and boasts some of the clearest skies in July of any location in the path of totality. Some slight cumulus clouds do form each day over southern Baja's Sierra de la Laguna range of mountains, but these should not pose a threat unless you have chosen a site in the mountains or foothills.

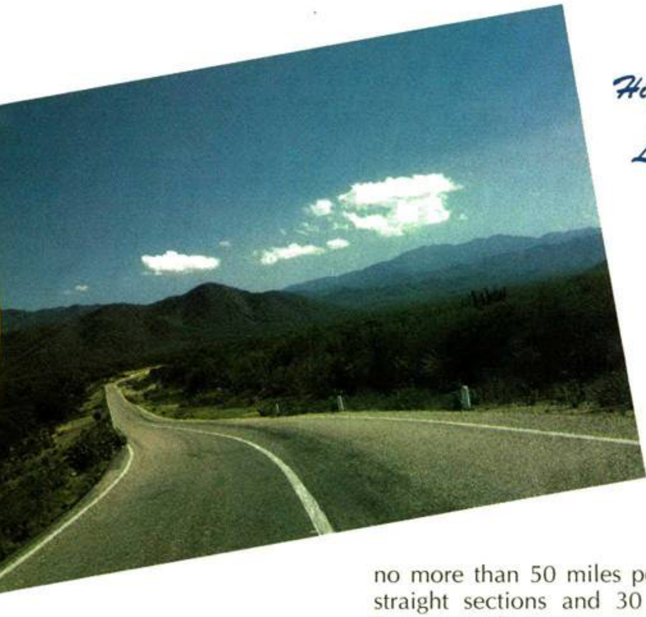
The next best Mexican site is along the west coast south of Mazatlán near Tuxpan. Again, clouds form over the inland mountains but the coastal area itself is often clear. Those who are not able to make it to Baja and who have yet to make travel plans should try for the west coast area, though services and accommodations are being taxed to the limit there, too.

But it's Baja that beckons for most eclipse fans. One of the attractions is that the sparsely populated peninsula is traversed by a relatively new two-lane highway, the Transpeninsular Highway 1, completed in late 1973.

If you're planning to drive to the Baja be prepared for conditions very different from those you are familiar with on U. S. superhighways. First, the roadbed of Highway 1 is elevated, at times a great distance above the surrounding terrain. This results in a lack of shoulders on either side of the highway. In addition, the road averages a total width of 19 to 25 feet, very narrow by U. S. standards. This becomes a problem when you drive a motor home or RV or when you encounter one on the highway. Through the southern third of Baja the road also winds, and the average speed recommended by the American Automobile Association is



BAJA
MEXICO


Highway 1 south of La Paz.

The Baja landscape near Santiago.

Clouds over the central Sierra de la Laguna mountains.

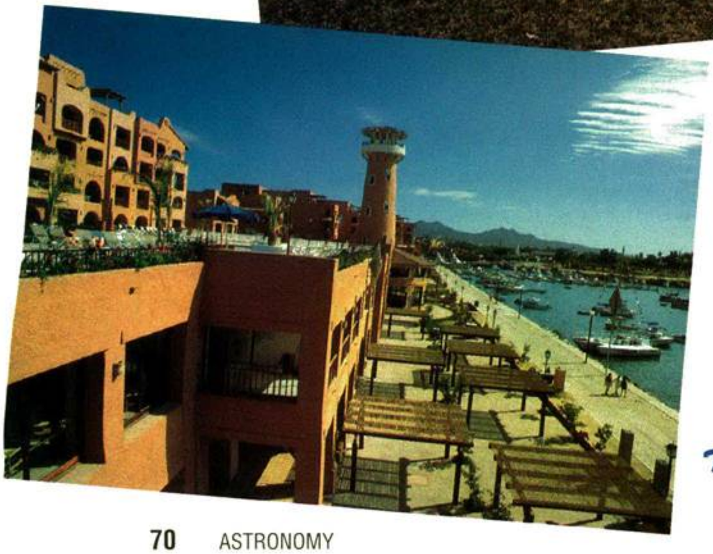
no more than 50 miles per hour on straight sections and 30 miles per hour around curves.

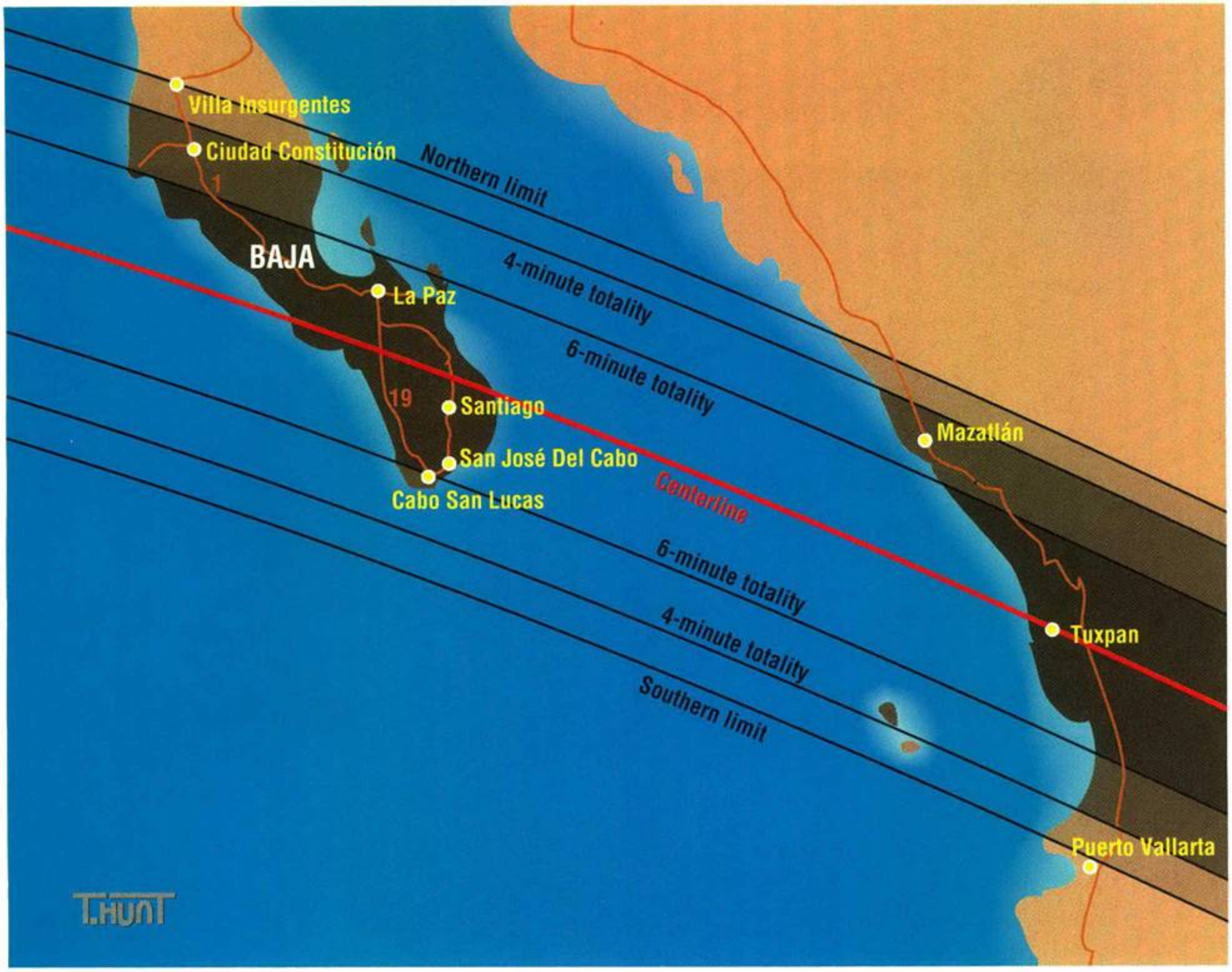
Highway 1 is also not well lit. If you were planning to make time by driving through the night, be aware that doing so can be downright dangerous. Many large ranchos are situated on either side of the road. Cows, horses, and mules often wander out onto the highway at night seeking the warmth of the roadbed.

As if the foregoing were not enough, remember you'll be travelling in the middle of summer, when local daytime temperatures can soar past 100° F. Your car or truck must be in top mechanical condition, or else you'll risk a breakdown that can lead to life-threatening isolation in hostile climatic conditions. The best advice is to carry plenty of potable water. To help drivers in distress, the Mexican government will be putting on extra units of the so-called Green Angels. These service vehicles run daily patrols of the main tourist highways in Baja and mainland Mexico.

Normally the 1000-mile drive down to the southern tip of Baja takes two or three days. But these are not typical circumstances. I'd strongly advise drivers to depart southern California no later than the weekend of July 5 to 7, if they intend to arrive somewhere in the path of totality (south of Villa Insurgentes) in time for the event. If you are coming from southern Arizona or Texas, you'd better tack on another 3 days as a buffer.

Taking several days to drive the length of Baja raises the question of where to sleep. You will not want to sleep in your vehicle, both due to the climate and for reasons of personal safety. Fortunately, towns like Ensenada, San Quintín, Guerrero Negro, Mulegé, Loreto, and La Paz all have a fair quantity of hotels and


The inner harbor at Cabo San Lucas.



resorts. The problem will be that as you travel south into the path of totality, hotels will become fully booked. As of late February, all the hotels south of Guerrero Negro (at the border between the states of Baja California and Baja California Sur) were booked solid the week of the eclipse and nearly booked the weekend prior to the event.

If you are driving a motor home or RV to the eclipse, you will be faced with full RV camps. Contrary to scuttlebutt, you cannot camp out on the beaches in Baja at your own discretion. Many of these sites belong to either private homeowners or hotels. Squatting on such property without gaining permission can result in some rather embarrassing, if not legally troublesome, consequences.

Sailing the Sea of Cortés

If you have a private pilot's license and plan to fly down to Baja for the eclipse you'll need to file a flight plan, make prior arrangements with whatever private, noncontrolled airstrip you plan to tie down at, and check with local authorities about the availability of aviation fuel. Private flights into and out of the eclipse path less than 24 hours before the event will be prohibited within the 6-minute isochronic lines shown on the map above.

Do you have your own private sail or power boat? Be sure you have a guaranteed slip at your destination port, unless you plan on staying at sea the entire time you are in the waters off southern Baja. Also, check with local marine authorities about where to get marine fuel, as this commodity may be in short supply the week of the eclipse.

Those coming from points east of California or Arizona have another option for approaching the Baja. It is possible to enter Mexico from New Mexico or Texas and then drive down one of the main Mexican highways toward the coastal cities of Mazatlán (which is in the eclipse path) or Puerto Vallarta (which is just south of the path) and then cross the Sea of Cortés via ferryboat. Ferry service from Mazatlán to La Paz runs daily, from Puerto Vallarta to La Paz on Fridays only, and to Cabo San Lucas on Tuesdays and Saturdays only. The crossing averages a tidy 18 to 24 hours, and the waters in the Sea of Cortés can be very rough at times.

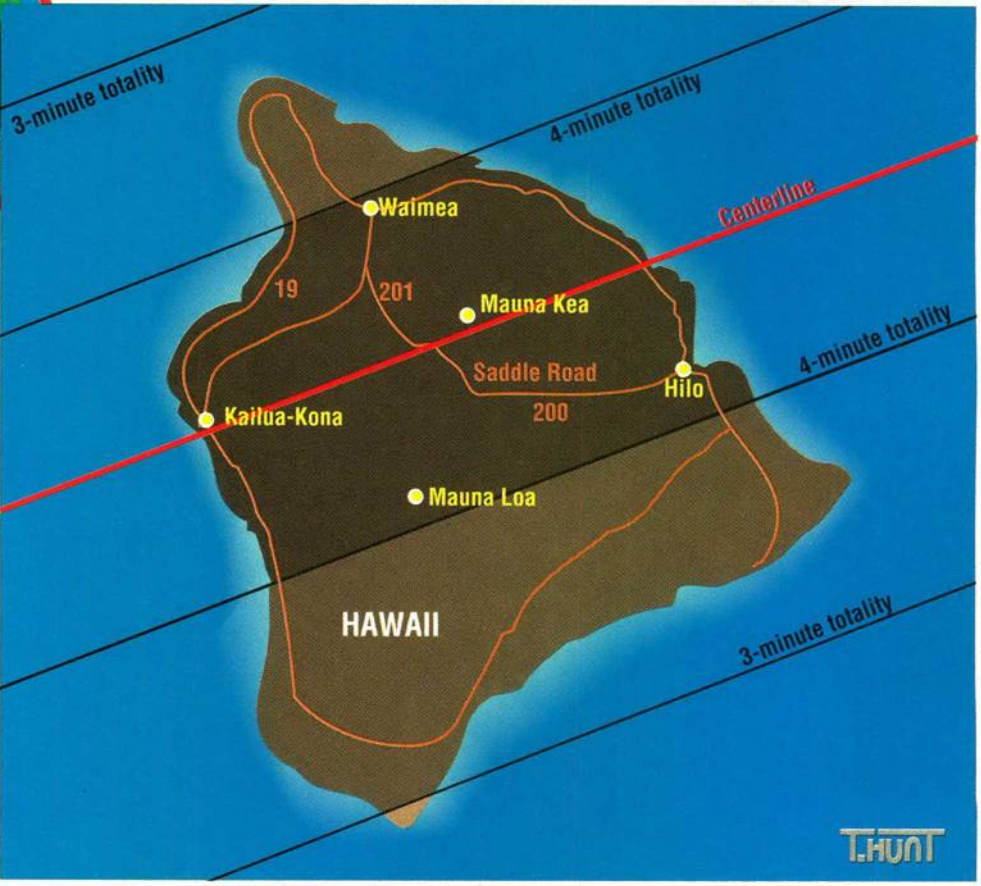
Cost of the ferry ride is inexpensive, either with your vehicle or just riding as a passenger. However, you must personally stand in line at the ferry office and buy your tickets at least 72 hours in advance. Also, the persons at ferry offices speak only Spanish.

Buying the Basics

Under normal conditions, southern Baja is capable of supporting most of the millions of tourists that annually fly, drive, or boat into the region for a holiday. Restaurants are plentiful and many of them happily accept U. S. dollars as well as the Mexican peso. (Canadians should use U. S. travellers checks, not Canadian ones.)

Gasoline in Baja is provided by PEMEX, the national petroleum company. You'll find two basic grades of auto fuel in Baja; *nova*, the leaded regular 75 octane fuel, and *magna sin*, the new name for unleaded fuel. *Nova* is by far the most plentiful. With the extra number of U. S. vehicles designed to run only on un-

Under Hawaiian Skies



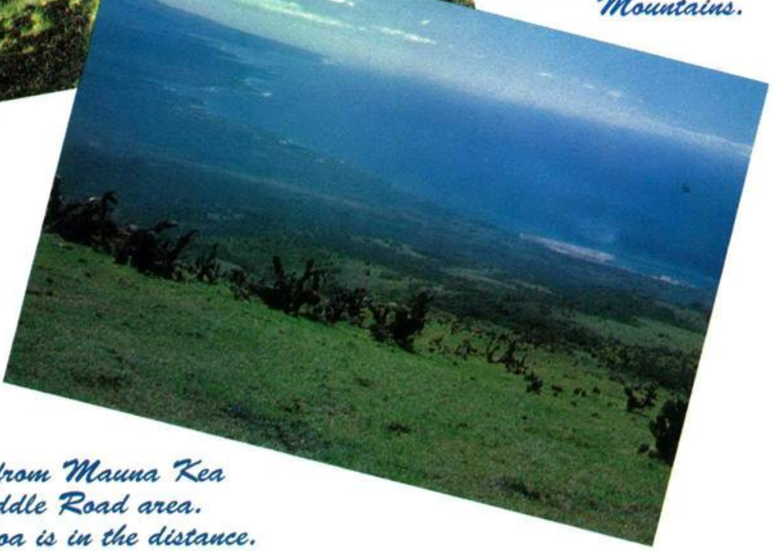
Just after first touching the surface of the Earth, the shadow of the Moon crosses the Big Island of Hawaii. Viewers will see a total eclipse nearly 4 minutes long beginning at 7:28 a.m. local time. (The eclipse path also grazes the remote southern shore of Maui.) Although the eclipse is 97- to 99-percent partial on the other Hawaiian islands, the difference between the views from those sites and the view of the 100-percent total eclipse from the Big Island is like the difference between day and night. You need to be on the island of Hawaii.

Like the Mexican sites, facilities and resources on Hawaii will be strained to the limit. Officials expect 30,000 to 60,000 people above the normal tourist level for July. According to Harry Kim, coordinator of the island's civil defense operations, "People who don't have advance reservations for rooms and rental cars will be inviting difficult times for themselves, especially if they have children." For example, anyone thinking of camping is being warned against it. Campsites are limited and random camping on public lands will not be allowed. Although private camping areas may open to take advantage of the eclipse, officials said visitors should not count on them.

On the morning of the eclipse, all roads around the island will be open, with the exception of the two roads that start at the Saddle Road (Highway 200) and head up Mauna Kea and Mauna Loa. These roads will be closed starting July 10 and will not reopen until July 12. The Saddle Road itself will remain open but there will be no parking allowed along its narrow, winding 55-mile length. There will also be no parking at the Pohakuloa Military Camp midway along the Saddle Road. Parking will be allowed along Queen Kaahumanu Highway (Highway 19) along the Kona Coast north of Kona, the prime viewing area. But police will be patrolling the highway and towing any vehicles that block traffic. For up-to-date information on Hawaii's eclipse plans, visitors should call the island's Eclipse Hotline at (808) 329-8484.

If you are planning to visit the Mauna Kea Observatories, you will need to rent a four-wheel drive vehicle for the trip to the 14,000-foot summit. During eclipse week, security officers will be stationed at the visitors' center at the 9,000-foot level of Mauna Kea (where the pavement ends) to enforce the 4WD-only rules and restrict travel beyond that point. However, several tour companies will be operating conducted trips to the summit. Contact the Hawaiian Resort Transportation Company (775-7291), Paradise Safaris (329-9282), or the Waipio Valley Tours and Shuttle Company (775-7121) — all area code 808 — for more information. In addition, the visitor center will be conducting public stargazing sessions at the 9,000-foot level on the weekends prior to and following the eclipse. — *Alan Dyer*

Lava flows along the Kona Coast with Maui on the horizon.



Looking south along the Kona Coast from the Kohala Mountains.

The view from Mauna Kea over theSaddle Road area. Mauna Loa is in the distance.

The summit of Mauna Kea. The Keck Telescope's the middle one.

leaded gas hitting the roads of Baja, the availability of unleaded gas may be a problem in more remote stretches of Highway 1. A site inspection this spring revealed new green-and-white road signs on Highway 1 indicating the distance in kilometers to the next *magna sin* service. But even with additional stocks of this fuel brought in for the event, supplies may dwindle as the eclipse week progresses. Remember, you not only want to get to the eclipse, you want to get back. Also, PEMEX stations do not accept U. S. credit cards. You'll need cash.

With accommodations being in such short supply, only brand new resorts, some of which may not be open in time, might provide some ray of hope for those trying to get last-minute rooms. Be wary of anyone trying to rent you their personal apartment or condominium, especially in Los Cabos. Rumors have it that some privately held apartments are going for as high as $500 a day just for a condo with no basic services, porterage, maid service, or restaurant on the premises for guests.

Medical facilities are scattered throughout Baja, but remember this is a frontier province of a near-third-world nation, so the quality of medical care is commensurate with the region. Bring along extra prescriptions for vital medicines, and exercise discretion over how much, where, and when you eat or drink. Most visitors to Mexico fear a case of "Montezuma's revenge," but the fact is that over half of these incidents could be avoided simply by practicing moderation when consuming liquor, fresh fruits, and highly spiced dishes not normally eaten. In all my visits to the Baja in the last two years, I have yet to contract stomach problems. The water is safe, and it is normally purified in all major resorts and hotels.

The Hand of Government

With tens of thousands of people expected to descend upon Baja for the eclipse, the local government has quite a task on its hands. The highest concern of the office of the Secretariat of Tourism in La Paz is crowd control the day of the eclipse. Visions of miles-long traffic jams both in the city and on the long, narrow Transpeninsular Highway have given rise to fears of potential disaster.

The action local officials will be taking to prevent total gridlock on July 11 will be direct and simple: the government in Baja will allow a maximum of 25,000 persons (not ve-

Advice for Nomadic Astronomers

by Phil Harrington

With visions of prominences dancing in their heads, many amateur astronomers are wondering how they can safely get their delicate cameras and telescopes to the path of totality. If you're flying to the eclipse, here are some tips to consider before tossing that expensive equipment onto the baggage conveyor.

Fortunately, cameras and lenses are small enough to be brought on the plane as carry-on items. However, you should pack all camera equipment in a compartmentalized gadget bag. Like luggage, camera bags come in two basic varieties: hard shell and soft-sided cases. If the bag is always going to be safely at your side, either type should suffice. Personally, I have travelled for years with an oversized vinyl gadget bag without incident. Into it I have crammed two 35mm cameras, 28mm and 400mm lenses, a mini-tripod, and a flash, and I have still managed to squeeze in a pair of 11x80 binoculars. That's the big advantage of soft bags — they stretch!

If you are worried your camera gear may get banged around, a foam-lined hard case is your best choice. Select one that is strongly reinforced and equipped with rugged hinges and a lock. If it is a keyed lock, be sure to bring two copies of the key, stored in separate places in your luggage.

Film, like all parcels brought on board aircraft, is subject to airport security inspection, usually with x-ray machines. Several companies market small film storage bags or boxes that are impervious to x-rays. Another approach is to put each roll of film into a clear plastic canister, like the ones Fuji film comes in, then place them all in a clear plastic bag. (Ask a friendly local lab to save the clear film cans for you.) This makes a hand inspection at the security point much easier, avoiding the x-ray machine altogether.

BEAUTIFUL
HAWAII
Baja
Beckons
VISIT
MEXICO

Transporting telescopes presents additional challenges. Except for the smallest models, you can't carry them onto the plane with you. There are no industry-wide policies regarding the transport of telescopes by air. Some airlines permit telescopes to be checked as baggage, provided they do not exceed size and weight restrictions. In that case, it would be a good idea to purchase extra luggage insurance. Other airlines do not consider telescopes to be check-in items. You must ship the instrument separately ahead of time via an air cargo carrier. Contact your carrier or tour director well ahead of departure day to find out the rules.

If you own the typical 8-inch Schmidt-Cassegrain, do not ship it in its standard footlocker-style carrying case. Meade recommends a home-constructed wooden crate made of 2" by 2" wooden framing and 1/2" plywood side panels. The interior dimensions should be the same as the manufacturer's case to permit using their pre-cut foam padding. According to Celestron, their hard plastic cases, like those that come with their Ultima and Powerstar models, are strong enough to take the punishment that air cargo can go through.

No matter what case you use, take a few additional precautions before waving goodbye to your telescope on the loading ramp. Completely enclose the telescope in protective bubble wrap. Use the variety that has about 1-inch diameter bubbles. Place the telescope, case and all, into a heavy-duty multi-walled cardboard box. This may be purchased from companies that specialize in wrapping equipment for shipment.

If you own another type of telescope, one idea would be to remove the optics and place them into a suitable case that you can carry on the plane. The empty tube may then be bubble-wrapped, surrounded by Styrofoam "popcorn" both inside and outside the tube, then placed into a strong wooden crate. Be certain the shipping carton can be used again on the return trip. Bring along a roll of packing tape just in case you need to effect emergency repairs. Also take a set of jeweller's screwdrivers for your cameras and lenses as well as any other tools you may need to assemble your equipment.

Due to their weight, tripods and mountings pose special problems. I have travelled by air with a large tripod by first wrapping it in thick sleeping bags then packing it into a large tent carrying case made of rip-stop nylon. Heavy equatorial mountings, however, demand to be professionally packed. Seek out a local company for help.

Considering the effort involved, the best advice for taking a telescope to the eclipse is — don't. Spectacular views of the eclipse are possible through binoculars, while striking photos can be taken through 400mm to 1000mm telephoto lenses (see "How to Photograph the Eclipse," April 1991). A telescope is not essential.

As a final word of advice, you should compile an inventory, with serial numbers, descriptions, and values, of all the equipment you are taking. This will help air carriers find lost equipment. This list should also be presented and registered with U. S. Customs at your point of departure. You don't want to pay customs duty on equipment because the officer thinks you purchased it on your trip. With some careful planning, your precious equipment should make it to the eclipse and back in one piece. Good luck on your trip, and *bon voyage*!

Eclipse
1991

hicles, but people) to enter southern Baja the week before the eclipse. Checkpoints are being established along the length of Highway 1, particularly in Tijuana, Ensenada, and Guerrero Negro. At each point, visitors will be asked their final destination in Baja.

At Guerrero Negro, vehicles continuing into Baja California Sur will be issued a special placard to place in their front car window. After the first 25,000 tourists enter the state, no further passes will be issued. Any further vehicles coming to the border at Guerrero Negro will be turned back, regardless of whether the drivers possess accommodations in Baja Sur or not.

Those driving to Baja with motor homes or RVs will be asked if they have reservations at a trailer park or RV camp. If not, they will be directed to a site of the government's choosing, as drivers will not be allowed to just pull off the side of the highway anywhere they choose.

Another measure the Mexican government is taking to reduce traffic problems the day of the eclipse itself is that approximately 3 hours prior to the start of the eclipse, Highway 1 south of La Paz will be closed to all vehicular traffic. This will be about 7:00 a.m. local time. (Baja Sur is on Mountain Standard Time year round — it does not observe Daylight Saving Time.) Checkpoints will be set up to stop vehicles, and you will not be permitted to move your car until after the end of totality. If you are travelling to an observing site, you had better be on site by the "witching hour."

Despite some antiquated information in the AAA tourist information book on Baja, all types of electronic, optical, camera, and other visual and audio recording devices are being allowed into Baja for the eclipse. Further, the rumor that tripods will be confiscated upon entry into the country is totally unfounded. However, it *is* true that all telescopes and sophisticated and unusual electronic gear need to be registered with Mexican authorities before you enter the country. If you are travelling with a tour group, consult your expedition directors for registration procedures. If you are travelling independently, contact either the Mexican Government Tourism Bureau Office in Los Angeles, or the Baja Sur office in La Paz, Mexico, for the necessary forms.

All persons entering Mexico must complete a simple tourist information card prior to entering the country. The form will either be given to you on your flight or can be obtained at any AAA office in major cities near the Mexican border. This requirement extends to all entrants, regardless of age. In addition, you must possess a valid proof of citizenship. A driver's license is not sufficient. A certified copy of a birth certificate accompanied by some identification with your photo on it is acceptable, but the best form of identification is a passport. It must be valid for at least 6 months past the dates of your travel.

Finally, if you are driving into Baja with your vehicle, you will need to get a car permit, with large trailers requiring their own permit. You can get these permits at the port of entry but you'll need to supply proof of ownership of your vehicle. All drivers, even those renting a car upon arrival, are also required to take out auto insurance. The insurance must be issued by a Mexican-based company, not the normal hometown firm you already use. Mexico does not accept U. S. insurance coverage and if you are involved in an accident, regardless of how minor it is, it is considered a felony by the Mexican authorities. If you do not possess proper coverage, you will likely be jailed, and the judicial system in Mexico is notoriously slow. You do not want to watch the eclipse through the bars of the local *estacion de policia*!

Who to Contact

Those still making plans to get to the eclipse should not wait any longer. To help you organize your trip, I suggest you contact the following agencies:

Mexican Government Tourism Office, 10100 Santa Monica Boulevard, Suite 224, Los Angeles, CA 90067, (213) 203-8191; Fax: (213) 203-8316. This is the clearinghouse for most tourist information about the Baja. They can direct you to possible last-minute solutions for campsites, RV parks, and home stays in Baja. They will also have telescope registration forms for those individuals coming to Baja with their scope.

Secretariat of Tourism, Director of Control and Operations Coordination, KM 5.5 Transpeninsular Carretera 1, Apartado Postal Numbro 419, La Paz, B.C.S., México 23090. Telephone 011-52-682-2-11-99, 2-80-19, or 2-79-75. FAX: 52-682-2-77-22. This is the main department in La Paz, Baja, for coordinating eclipse preparations in southern Baja. Some knowledge of Spanish will make communications easier.

The Automobile Club of Southern California, 2601 South Figueroa Street, Los Angeles, CA 90007, (213) 277-0900. This group has an excellent road map of Baja free of charge to AAA members, plus other travel guides.

Baja Trail Publications, Inc., P. O. Box 8088, Huntington Beach, CA 92615. This publishing house offers an excellent kilometer-by-kilometer descriptive guidebook to the Transpeninsular Highway.

Next month's big event will certainly be an adventure for everyone travelling to the path of totality. The watchwords for eclipse chasers are — relax, be very patient, and remain flexible. The reward will be the once-in-a-lifetime experience of an awe-inspiring natural phenomenon — a total eclipse of the Sun. ☐

Joel K. Harris is founder and director of Twilight Tours, an astronomical and science expedition organizing firm in Burbank, California. He is leading a major expedition to observe this July's eclipse in Los Cabos, Baja Mexico. His last article, "An (Optical) Revolution in Chile," appeared in the November 1990 issue.

The Dance of the Jovian Moons

As early results from the series of mutual eclipses and occultations roll in, it's time to get ready for the series' exciting conclusion.

by John E. Westfall

Your telescope is the ticket to some fascinating sights during the coming months. Jupiter's four large satellites are currently eclipsing and occulting one another, and these events are easy to see even in small telescopes.

Once every six Earth years, or half a Jovian year, the geometry of the Sun, Earth, and Jupiter is just right so that mutual events can occur. We are currently in the midst of an eighteen-month-long series of over 300 mutual events that began in November 1990 and will last until April 1992. (See "Watch Jupiter's Moons Play Tag" in the January 1991 issue.)

Jupiter's four Galilean satellites — Io, Europa, Ganymede, and Callisto — orbit nearly in the plane of the giant planet's equator. But mutual events only occur when the Sun and Earth also lie near the same plane. When the Sun is approximately in the satellites' orbital planes, a Galilean satellite can cast a shadow upon another, resulting in a mutual eclipse. When Earth passes near the bodies' orbital planes, one satellite can block another from our view, giving us a mutual occultation.

The view you see in your telescope depends on several factors. During a mutual eclipse the two satellites appear separate, with the eclipsed one dimming over a period that lasts from a few minutes to over an hour. The amount that the satellite's light wanes is determined by the relative sizes of the two bodies and on whether the shadow of the eclipsing moon grazes the eclipsed moon or passes centrally across it. The light loss can range from effectively zero up to 100 percent. When the light loss approaches 100 percent, the eclipsed satellite not only dims, it disappears!

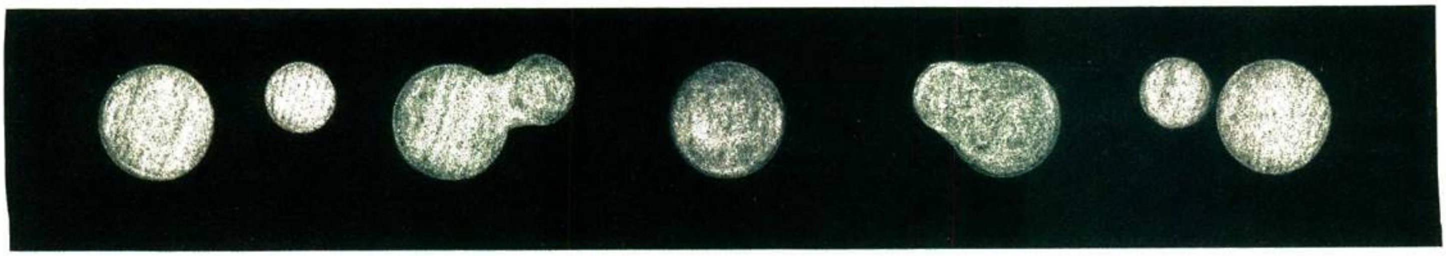
A mutual occultation develops quite differently than an eclipse. In an occultation, the two bodies initially appear separate. The distance between the two moons then closes until they blend together into a single elongated image. This combined image dims when the nearer satellite actually blocks all or part of the farther one from our view. After the moment of minimum light, the sequence plays out in reverse. The entire occultation can last anywhere from a few minutes up to an hour or more. How much dimming takes place depends on how much of the occulted satellite is covered and on the relative albedos (reflecting powers) of the two bodies. The light loss in a mutual occultation never exceeds about 62 percent because the satellite that is closer to us remains visible throughout the event.

In telescopes smaller than about 6 inches in aperture, you can't see an eclipse unless the light loss exceeds about 20 percent. This is true even if you carefully compare the brightness of the eclipsed satellite with that of another satellite. On the other hand, an ongoing mutual occultation is always evident, even in a small telescope.

If you observe with a bigger telescope, you'll get a better view. On a night of exceptional seeing, a 12-inch or larger telescope with excellent optics may show you the shadow of one satellite moving across the disk of another satellite during an eclipse, or a satellite passing in front of another one during an occultation.

Keeping a Record

Viewing a mutual event at the eyepiece is both fun and rewarding. But many observers go beyond this and record the events, either for their own use or to help professional astronomers better understand the Jovian satellite system. There are several ways you can do this. The simplest is to make a series of sketches, spaced a few minutes apart and timed to an accuracy of about 0.1 minute, while the event is in progress. You can supplement the sketches by visually estimating how the eclipsed or occulted satellite's brightness compares with the bright-



TWO SATELLITES BECAME ONE when Europa occulted Ganymede on November 20, 1990. Paul Smith sketched the view through his 6-inch f/6 telescope beginning at 4h56m UT (left) and continuing at 5h04m UT, 5h09m UT (center, at mid-occultation), 5h16m UT, and 5h18m UT (right).

nesses of two of the other satellites. Ideally, one of the comparison satellites should be brighter than your subject and the other one fainter.

You can achieve a more objective record quite easily through photography. As a guide to the proper exposure time, I've obtained clear images of the satellites with 4-second exposures using a 10-inch telescope and ISO 200 slide film. Space successive exposures a few minutes apart. You can also videotape a mutual event, though you need a telescope at least 14 inches in aperture to get clear satellite images.

Two more advanced ways to record mutual events are with a photoelectric photometer or a CCD camera. If you use a photometer, take V (visual) band readings every second if you can. (For occultations of Io by Europa, you should alternate rapidly between V and B (blue) readings. The two-color readings can help astronomers map volcanic eruptions on Io because fresh volcanic material has a different color than older deposits.) With a CCD camera, take images at short time intervals and be sure that you can rapidly store quite a few megabytes of data! If you use one of these more advanced methods, time your measurements to an accuracy of 1 second or better.

If you want to contribute your observations to science, you need to send them to a person who coordinates these studies. Electronic data, such as tapes, disks, printouts, and light-curves, should be submitted to both Dr. Fred Franklin, Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138 and Dr. Jean E. Arlot, Bureau des Longitudes, 77 avenue Denfert-Rochereau, 75014-Paris, France. You can send drawings and photographs of mutual events, as well as copies of VHS or S-VHS videotapes, to me at P. O. Box 16131, San Francisco, CA 94116. These submissions may be selected for publication by the Association of Lunar and Planetary Observers.

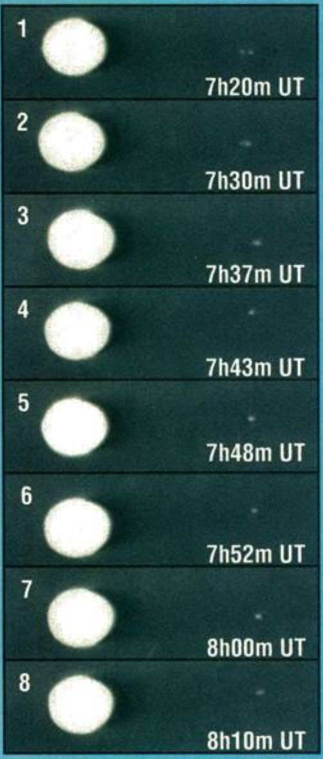
On these pages, you can see some of the different techniques used to record mutual events earlier in this series. One event in particular stands out — the January 26, 1991 event when Europa eclipsed Io and then immediately occulted it. As a matter of fact, the occultation began before the eclipse ended! The box at right shows some of the ways observers chose to record this rare event.

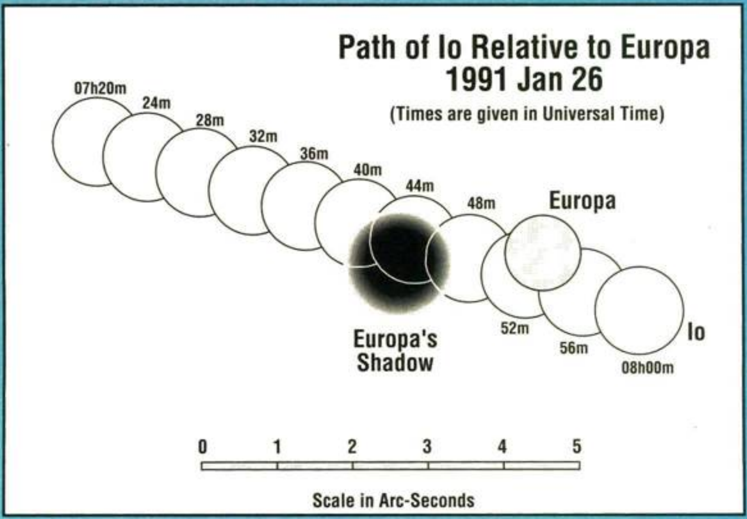
The Best of the Rest

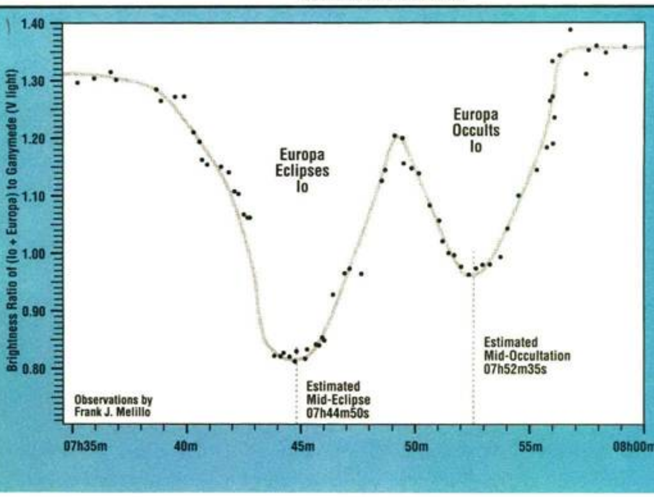
With Jupiter now slipping down into the evening twilight, the number

A SPECIAL EVENT

Perhaps the most spectacular mutual event so far occurred on January 26, 1991, when Europa nearly simultaneously eclipsed and occulted Io. A series of eight sample frames from a videotape taken by Jay Edwards and James Eggleston through a 14-inch Schmidt-Cassegrain telescope (right) shows the entire sequence. Io starts to the right of Europa (frame 1), then the two approach one another and the action begins. The eclipse runs from frame 3 to frame 5 and is near maximum in frame 4. The occultation begins in frame 5, is near maximum in frame 6, and ends in frame 7. By frame 8 Io is moving away to the left of Europa. Compare the videotape results with the light curve derived from Frank Melillo's photoelectric measurements of the combined brightnesses of the two satellites (bottom). Only through a detailed analysis of observations like these will astronomers learn how closely Io's actual path fell to the one predicted before the event (middle).







SCHEDULE OF MUTUAL EVENTS

UT Date	Event	Type of Event	UT Begin	UT End	DL	R
June 2	I ecl. C	P	10:54	11:03	0%	2
June 2	E ecl. G	A	14:11	14:19	32%	7
June 3	E occ. I	P	00:04	00:08	16%	3
June 4	G ecl. C	P	07:00	07:20	26%	18
June 4	I ecl. E	P	08:28	08:33	37%	3
June 5	**G occ. E**	**P**	**01:13**	**01:19**	**14%**	**7**
June 5	G ecl. I	P	08:25	08:38	98%	6
June 5	G ecl. I	P	23:24	23:52	45%	3
June 6	**G ecl. I**	**P**	**05:52**	**06:16**	**38%**	**6**
June 6	E occ. I	P	13:14	13:18	20%	3
June 7	I ecl. E	P	21:36	21:42	31%	4
June 9	E ecl. G	A	17:25	17:33	45%	6
June 10	**E occ. I**	**P**	**02:24**	**02:28**	**25%**	**3**
June 10	**C ecl. G**	**P**	**04:03**	**04:15**	**15%**	**11**
June 11	**C ecl. I**	**P**	**04:45**	**04:58**	**4%**	**1**
June 11	I ecl. E	P	10:45	10:51	26%	4
June 11	C ecl. I	P	17:01	17:12	7%	5
June 12	**G occ. E**	**P**	**04:47**	**04:54**	**32%**	**8**
June 12	G ecl. I	P	12:01	12:18	95%	6
June 12	G ecl. I	P	21:38	22:04	77%	0
June 13	G ecl. I	P	10:06	10:19	59%	6
June 13	E occ. I	P	15:34	15:38	30%	3
June 14	I ecl. E	P	23:54	23:59	22%	4
June 16	E ecl. G	A	20:39	20:48	33%	6
June 17	**E occ. I**	**P**	**04:45**	**04:49**	**35%**	**3**
June 18	I occ. E	P	11:39	11:41	1%	5
June 18	I ecl. E	P	13:03	13:08	18%	4
June 19	G occ. E	T	08:24	08:32	36%	8
June 19	G ecl. I	P	17:38	19:00	19%	4
June 19	I ecl. C	P	20:17	20:19	0%	7
June 19	G ecl. C	P	20:28	20:35	1%	7
June 20	**E ecl. C**	**P**	**04:44**	**04:50**	**0%**	**10**
June 20	G ecl. I	P	13:31	13:42	83%	5
June 20	E occ. I	P	17:56	18:00	40%	3
June 22	**I occ. E**	**P**	**00:51**	**00:54**	**5%**	**5**
June 22	**I ecl. E**	**P**	**02:13**	**02:18**	**13%**	**4**
June 23	E ecl. G	A	23:53	00:00	21%	5
June 24	E occ. I	P	07:06	07:10	37%	2
June 25	I occ. E	P	14:04	14:08	9%	5
June 25	I ecl. E	P	15:22	15:27	10%	4
June 26	G occ. E	T	12:04	12:13	36%	8
June 26	C occ. E	P	15:32	15:40	16%	9
June 26	G occ. I	P	17:30	17:54	6%	6
June 26	G occ. I	P	21:04	21:30	4%	4
June 27	C ecl. E	P	13:42	13:59	1%	2
June 27	G ecl. I	P	16:39	16:49	98%	5
June 27	E occ. I	P	20:17	20:20	35%	2
June 28	C ecl. E	P	19:21	19:35	24%	9
June 29	**I occ. E**	**P**	**03:18**	**03:22**	**16%**	**5**
June 29	**C occ. G**	**P**	**03:54**	**04:09**	**20%**	**15**
June 29	**I ecl. E**	**P**	**04:32**	**04:37**	**6%**	**4**
June 29	C ecl. G	P	10:07	10:11	0%	14
July 1	E ecl. G	P	03:07	03:13	5%	5
July 1	E occ. I	P	09:27	09:31	27%	2
July 2	I occ. E	P	16:31	16:36	22%	5
July 2	I ecl. E	P	17:42	17:47	4%	4
July 3	G occ. E	P	15:48	15:57	22%	8
July 4	G ecl. I	P	19:38	19:46	91%	4
July 4	E occ. I	P	22:38	22:42	20%	2
July 5	E occ. C	P	06:26	06:29	0%	7
July 6	I occ. E	P	05:46	05:52	30%	5
July 6	I ecl. E	P	06:53	06:57	2%	5

UT Date: The date in universal time (UT) on which the event begins. **Event**: The form of the event, where the satellites are labeled I for Io, E for Europa, G for Ganymede, and C for Callisto. The occulting or eclipsing satellite is given first, followed by "occ." for occultation or "ecl." for eclipse, and then by the occulted or eclipsed satellite. **Type of Event**: Whether the event is partial (P), total (T), or annular (A). **UT Begin and End**: The universal times of the event's beginning and end, each given in the form hh:mm. (Subtract 4 hours to convert to EDT, 5 hours for CDT, 6 hours for MDT, and 7 hours for PDT. Subtract an additional hour for standard time.) **DL**: The maximum light loss in percent. **R**: The apparent distance from Jupiter's center in Jovian equatorial radii. Events shown in boldface are visible from all or part of the contiguous United States. Events shown in blue can be observed visually but are not recommended for photoelectric photometry. The event predictions have been provided by F. Franklin, K. Aksnes, and J. E. Arlot.

of mutual events visible from any one region is decreasing. And to make matters worse, our view of Jupiter and of the mutual events will be interrupted for about two months centered on August 17, when Jupiter is in conjunction with the Sun. Subsequent events will be visible in the morning sky in the fall, with even a few laggards taking place in the spring of 1992. The table above lists all the mutual events predicted from now through April 1992, when the series comes to a close.

What makes one mutual event worth watching and another not is a matter of taste. Some people prefer eclipses, some prefer occultations, and some go for any event that occurs under exceptional circumstances. The following events, which are restricted largely to those visible from the United States, are ones that I feel are especially entertaining. (The dates given refer to the universal time at which the events start. Remember to subtract 4 hours for Eastern Daylight Time and 7 hours for Pacific Daylight Time.)

On the night of June 6, Ganymede eclipses Io and causes Io to dim by 38 percent. Four days later, on June 10, Europa passes in front of Io. The combined light of the two satellites drops by 25 percent.

At first glance, the eclipse of Io by Ganymede on June 11 looks pretty boring — Io dims by just 4 percent. The event's saving grace is that the shadows of the two satellites are transiting Jupiter during the event. In your eyepiece, you'll see the two shadows actually merge with each other on Jupiter's disk.

June 12 brings with it two events worth watching. North American observers can see Ganymede occult Europa with a 32-percent light loss. Then later that day European observers can see Ganymede eclipse Io. This event features a significant 77-percent light drop, and the shadows of both satellites will be in transit on Jupiter's disk and thus will blend together.

Europa occults Io on June 17. With a 35-percent light loss, this occultation will be easy to follow in the eyepiece.

On June 29, three events occur

UT Date	Event	Type of Event	UT Begin	UT End	DL	R
July 7	I ecl. G	P	20:28	20:34	14%	1
July 8	E ecl. G	P	06:21	06:24	0%	4
July 8	E occ. I	P	11:49	11:53	13%	2
July 9	I occ. E	P	19:01	19:07	37%	5
July 9	I ecl. E	P	20:04	20:08	1%	5
July 10	G occ. E	P	19:37	19:44	7%	9
July 11	G ecl. I	P	22:31	22:39	64%	4
July 12	E occ. I	P	01:00	01:03	7%	2
July 13	I occ. E	P	08:16	08:23	43%	6
July 13	I ecl. E	P	09:12	09:19	1%	5
July 14	C occ. I	P	01:48	01:54	60%	4
July 14	C occ. G	P	19:47	19:54	21%	4
July 14	I occ. G	P	22:00	22:04	8%	3
July 14	I ecl. G	P	23:14	23:20	5%	2
July 15	E occ. G	P	07:58	08:03	8%	3
July 15	E occ. I	P	14:12	14:14	2%	2
July 16	I occ. E	T	21:32	21:39	46%	6
July 16	I ecl. E	P	22:27	22:30	0%	5
July 17	G occ. E	P	23:32	23:34	0%	9
July 19	G occ. I	P	00:16	00:18	3%	4
July 19	G ecl. I	P	01:21	01:28	39%	3
July 20	I occ. E	P	10:50	10:56	44%	6
July 20	I ecl. E	P	11:39	11:42	0%	5
July 22	I occ. G	P	01:01	01:07	23%	4
July 22	I ecl. G	P	02:03	02:08	1%	3
July 22	I occ. C	P	05:30	05:35	1%	6
July 22	E occ. G	A	11:28	11:34	23%	2
July 22	I occ. C	P	16:37	16:50	7%	1
July 23	I occ. C	P	08:11	08:19	13%	5
July 24	I occ. E	P	00:07	00:14	38%	6
July 24	I ecl. E	P	00:52	00:54	0%	5
July 24	G occ. C	P	09:19	09:36	14%	14
July 26	G occ. I	P	03:18	03:23	20%	3
July 26	G ecl. I	P	04:08	04:14	13%	2
July 27	I occ. E	P	13:26	13:33	32%	6
July 27	I ecl. E	P	14:06	14:08	0%	6
July 29	I occ. G	A	04:07	04:14	29%	4
July 29	I ecl. G	P	04:56	04:59	0%	4
July 30	C occ. G	P	06:58	07:06	19%	10
July 31	I occ. E	P	02:45	02:52	26%	6
July 31	I ecl. E	P	03:20	03:22	0%	6
Aug. 2	G occ. I	T	06:19	06:24	40%	2
Aug. 2	G ecl. I	P	06:54	06:58	1%	2
Aug. 3	I occ. E	P	16:06	16:14	20%	6
Aug. 3	I ecl. E	P	16:36	16:37	0%	6
Aug. 5	I occ. G	P	07:18	07:26	25%	5
Aug. 7	I occ. E	P	05:28	05:36	15%	6
Aug. 9	G occ. I	P	09:18	09:23	37%	2
Aug. 10	I occ. E	P	18:52	19:00	10%	6
Aug. 12	I occ. G	P	10:40	10:47	13%	5
Aug. 14	I occ. E	P	08:19	08:26	6%	6
Aug. 17	I occ. E	P	21:50	21:57	3%	6
Aug. 19	I occ. G	P	14:19	14:27	6%	6
Aug. 20	I occ. G	A	03:18	03:42	29%	1
Aug. 20	I ecl. G	A	03:26	03:53	44%	1
Aug. 20	I ecl. G	P	12:07	12:25	23%	6
Aug. 20	I occ. G	A	12:19	12:36	29%	6
Aug. 21	I occ. E	P	11:25	11:31	1%	6
Aug. 24	G ecl. E	P	08:44	09:05	16%	9
Aug. 25	I occ. E	P	01:09	01:16	1%	6
Aug. 26	I occ. G	P	18:47	19:01	5%	6
Aug. 27	I occ. G	P	01:02	01:30	27%	2
Aug. 27	I ecl. G	P	01:48	02:15	30%	2
Aug. 27	I ecl. G	P	15:56	16:05	5%	5
Aug. 27	I occ. G	P	16:27	16:36	15%	6
Aug. 30	G occ. E	P	04:32	05:41	15%	8
Aug. 30	G occ. E	T	08:51	11:07	36%	5
Aug. 30	G ecl. E	P	11:31	12:42	98%	4
Aug. 31	G ecl. E	P	13:17	13:38	65%	9
Aug. 31	G occ. E	P	14:20	14:35	16%	9
Sep. 3	I ecl. G	P	19:15	19:18	0%	5
Sep. 3	I occ. G	P	20:02	20:04	0%	5
Sep. 7	G ecl. E	P	17:24	17:44	100%	9
Sep. 7	G occ. E	T	18:48	19:04	36%	9
Sep. 14	G ecl. E	P	21:19	21:36	97%	9
Sep. 14	G occ. E	P	23:03	23:15	25%	9
Sep. 22	G ecl. E	P	01:04	01:17	53%	9
Sep. 22	G occ. E	P	03:11	03:12	0%	9
Sep. 29	G ecl. E	P	04:43	04:52	9%	9
Oct. 6	**G ecl. E**	**P**	**08:19**	**08:21**	**0%**	**9**
Nov. 3	**G ecl. I**	**P**	**08:06**	**08:21**	**5%**	**0**
1992						
Mar. 22	**E ecl. G**	**A**	**08:08**	**09:32**	**36%**	**6**
Mar. 22	E ecl. G	P	15:17	15:52	0%	9
Mar. 29	**E occ. G**	**A**	**09:26**	**10:43**	**23%**	**5**
Mar. 29	E occ. G	P	16:37	16:53	0%	8
Apr. 5	**E ecl. G**	**P**	**02:14**	**03:08**	**23%**	**1**
Apr. 12	**E occ. G**	**P**	**05:02**	**05:49**	**22%**	**2**

within 79 minutes. The first is an occultation of Europa by Io, featuring a 16-percent light loss. The second is a rare occultation of Ganymede by Callisto in which the combined light of the two satellites drops by 20 percent. This event offers you a good chance to compare the dark-gray color of Callisto with the much brighter surface of Ganymede. The three-event mini-series ends with an eclipse of Europa by Io when Io dims by 6 percent.

After a gap of over four months, the next event worth viewing from North America occurs on November 3 when Ganymede eclipses Io. Although there is only a 5-percent light loss, this is another event during which the satellites' shadows simultaneously transit the disk of Jupiter and thus coalesce briefly.

By 1992 the mutual events are becoming quite infrequent. But on March 22, Europa eclipses Ganymede. This is a "slow" event, lasting 84 minutes, and the 36-percent light loss will be plain to the eye. A week later, on March 29, Europa occults Ganymede. This is another combination of a slow event (77 minutes) featuring a perceptible drop in brightness (23-percent light loss).

The series of mutual events comes to an end in April 1992 with two events visible from North America. On April 5, Europa eclipses Ganymede and Ganymede dims by 23 percent. The final event occurs on April 12 when Europa occults Ganymede and their combined light drops by 22 percent.

If you have not yet had a chance to see the unusual goings-on of Jupiter's four large satellites — there is still time. No matter where in the world you live, some of the remaining events will be visible. But take advantage of the opportunity now. You won't have the chance to view another mutual event until 1996. □

John E. Westfall is executive director of the Association of Lunar and Planetary Observers. He previewed the entire series of mutual events in his previous article, "Watch Jupiter's Moons Play Tag," in the January 1991 issue.

The Wonders of the Coma Cluster

Coma Berenices contains a star cluster you can see with the eye alone and also a rich group of galaxies to savor with your telescope.

by Alan Goldstein

This spring a great opportunity to explore deep-sky objects awaits you. With the naked eye and binoculars, you can view the star cluster making up the constellation Coma Berenices. With a telescope, you can peer far deeper into the realm of its galaxies. You can even explore the faint light of a remote cluster of galaxies. All you need is a free evening, the star map in this article, and a little patience.

Coma Berenices is unique among its peers. As constellations go it is small, and it's not even bright enough to be visible from moderately light-polluted areas. Yet its abundance of galaxies won't be found in many larger constellations. Most of its bright stars are members of the same star cluster. The star cluster isn't as compact as the Hyades or Pleiades because it is relatively nearby.

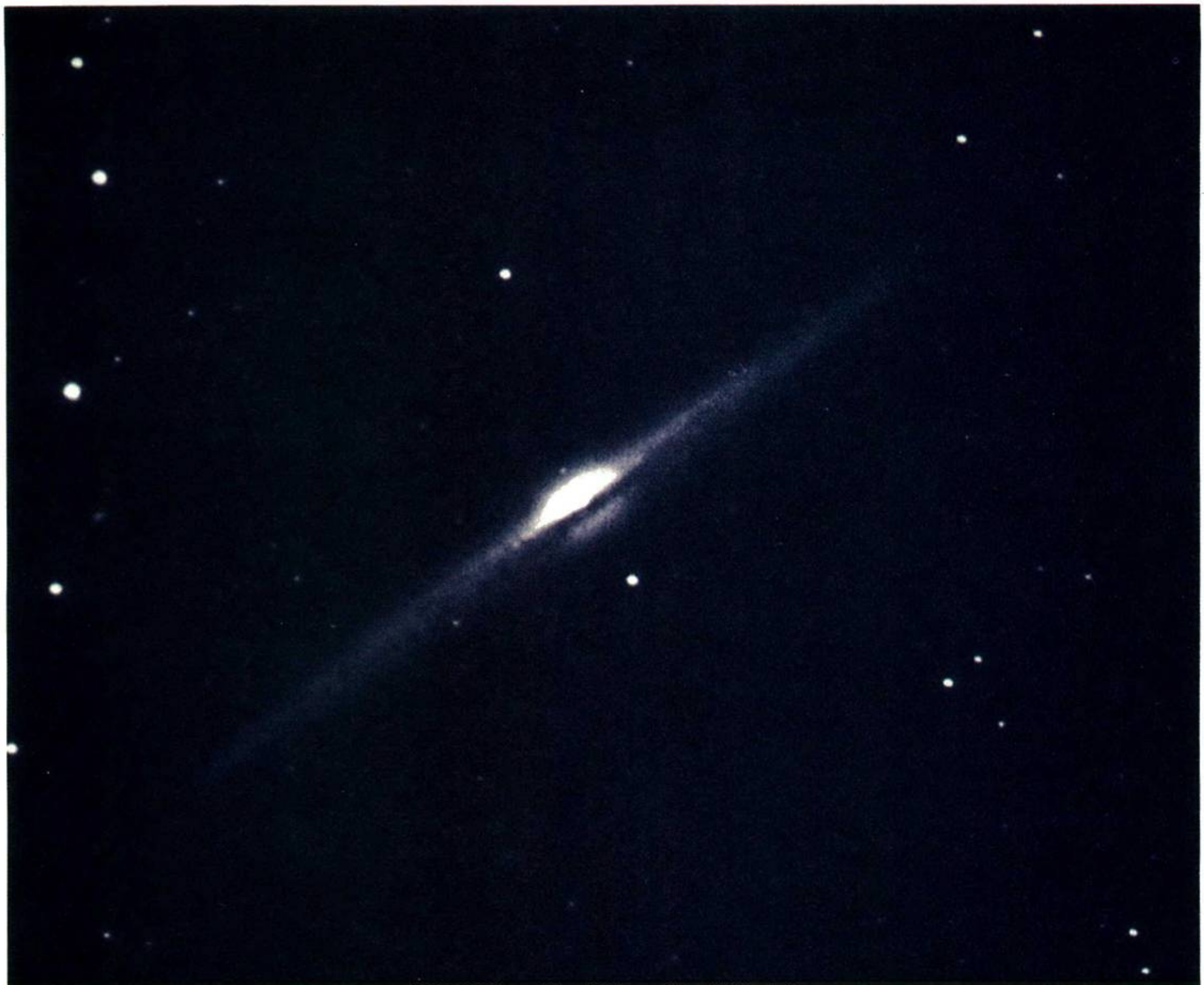
As you fix your gaze between Leo and Bootes, the first thing you'll see is a fuzzy patch of light several degrees across. This is the combined light from 50 or more stars in the **Coma Berenices star cluster** (Melotte 111). Just 250 light-years away, the Coma star cluster is in our cosmic backyard. In fact it is the third closest star cluster to Earth (after the Hyades in Taurus and the Ursa Major moving group, which is so close it does not look like a cluster at all). As we see the Coma star cluster, its members are strewn over an area of sky measuring 6° across, or twelve diameters of the Full Moon. Because the cluster is so large, it is best observed with a good pair of 7x50 binoculars.

Several members of the Coma star cluster are double or multiple stars. For example, **12 Comae Berenices** is a pretty triple star with a combined magnitude of 4.7. It is easy to find, being the brightest star on the western side of the cluster. Its companions are located 12" and 35" from the primary and glow at magnitudes 8.5 and 11.5, respectively. Another member of the cluster is **17 Comae Berenices**, a wide pair separated by 145". The brighter member shines at magnitude 5.4, the secondary at 6.7. The magnitude 6.7 star has a close companion separated by less than 2". At 13.7 magnitude, this faint star requires an 8-inch to 10-inch telescope to be seen. The star **24 Comae Berenices** is a beautiful multiple star system composed of magnitude 5.0 and 6.5 stars. To find this star, start at 17 Comae Berenices and star-hop 4° east-southeast to 23 Comae Berenices, then 4° due south to 24 Comae Berenices. Separated by 20.3", the yellow and blue stars in this pair are reminiscent of Albireo in Cygnus. Although slightly fainter that Albireo, 24 Comae Berenices is gorgeous in small telescopes.

NGC 4725 Mag. 8.9 Size 7.5' by 4.8'
by Rick Schrantz

Coma Berenices is best known for the many galaxies that lie within its borders. The finest is unquestionably the edge-on spiral **NGC 4565**, located less than 2° east of 17 Comae Berenices. At magnitude 10.2, this Sb-type galaxy is visible in small telescopes or a good pair of binoculars under excellent skies. Its dimensions are 15' by 1.1'. When you observe NGC 4565, you're now looking far beyond the 250-light-year distance of the Coma Star Cluster. NGC 4565 lies a whopping 30 million light-years away.

When you observe NGC 4565 you'll notice the galaxy is rich in dust. Many spiral galaxies contain large quantities of dark interstellar dust, and the most prominent feature of NGC 4565 is its thin central dust lane, which bisects this spindle-like object. Careful scrutiny reveals the galaxy's nucleus just north of this dust lane. In a 2-inch telescope this galaxy is visible as a slender ribbon of light. In a 4-incher you'll see the dark lane distinctly. In a 6-inch instrument you'll see the asymmetric nature of the dust lane and the galaxy's

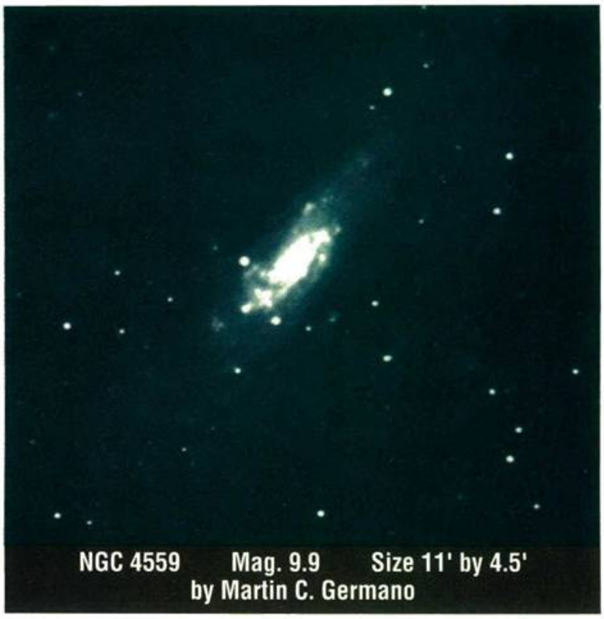


NGC 4565 Mag. 10.2 Size 15' by 1.1'
by Tom Eby

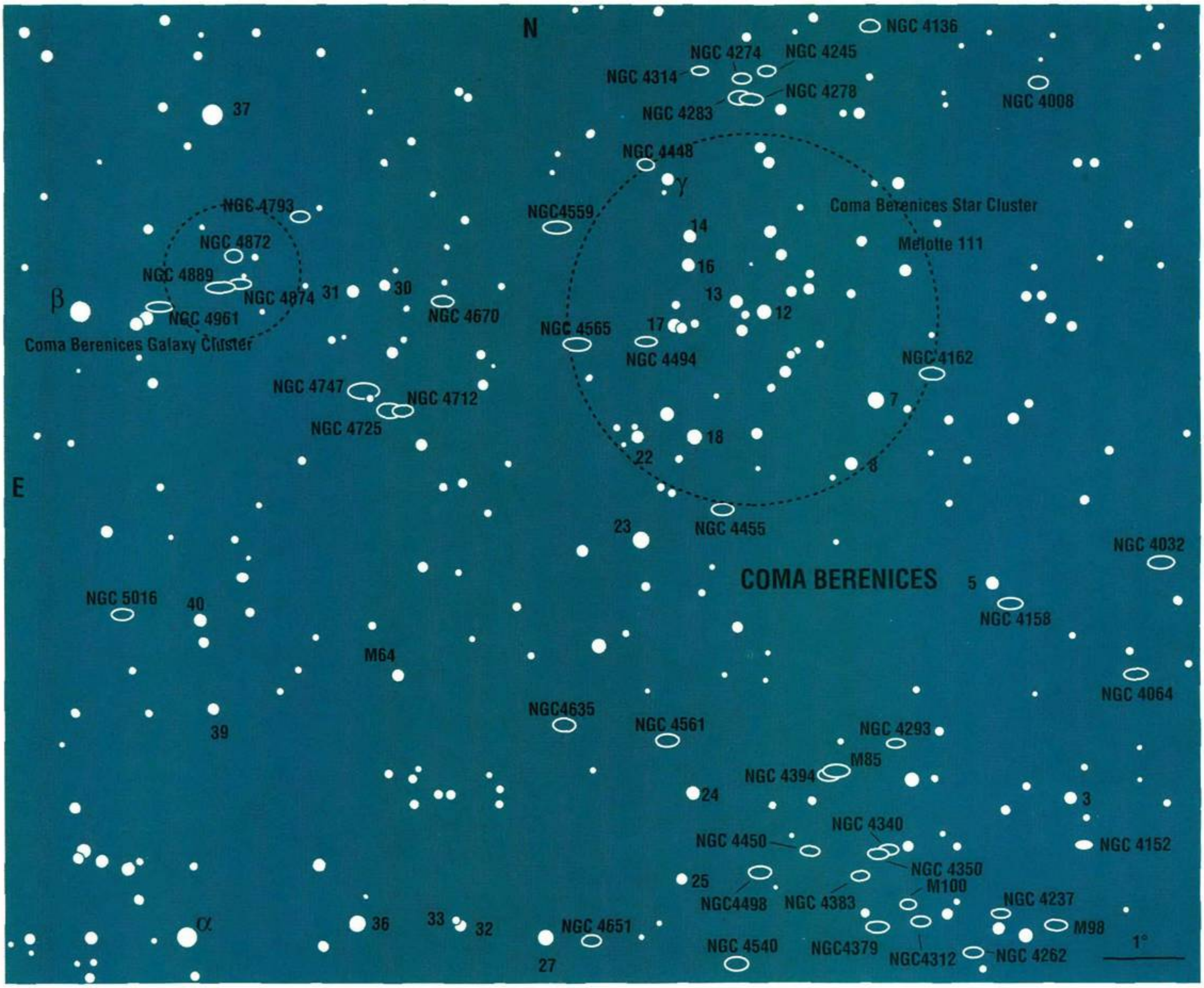
small, bright nucleus. A large telescope reveals subtle details in the dark lane.

Although they are not as spectacular as NGC 4565, many other galaxies lie nearby. You'll find **NGC 4494** just 1° west of NGC 4565. If you're using a small telescope, NGC 4494 might be passed by as a slightly out-of-focus star. It is located in the same field of view as 17 Comae Berenices. Like most elliptical galaxies, NGC 4494 bears magnification well — don't be afraid to try 150x or 200x to examine its details. **NGC 4448** lies just 3.5° northwest of NGC 4565 and within the same low-power field of view as the bright star Gamma Comae Berenices. NGC 4448 glows at magnitude 11.4 and measures 2.9' by 1.0' across. This compact type-Sb spiral galaxy is visible as a pale oval orb in a 3-inch telescope under superb skies and in a 4- or 5-inch scope under less than ideal conditions.

Also near NGC 4565 lies one of the largest galaxies in the constellation, **NGC 4559**. To find this galaxy simply center your scope on NGC 4565 and move 2.5° north in declination, to a point 2° east of Gamma Comae Berenices. NGC 4559 is a hefty object measur-



NGC 4559 Mag. 9.9 Size 11' by 4.5'
by Martin C. Germano


N
E
NGC 4136
NGC 4274
NGC 4245
NGC 4314
NGC 4278
NGC 4283
NGC 4008
37
NGC 4448
γ
Coma Berenices Star Cluster
Melotte 111
NGC 4793
NGC 4872
NGC4559
14
16
13
12
NGC 4889
NGC 4874
31
30
NGC 4670
β
NGC 4961
Coma Berenices Galaxy Cluster
NGC 4565
17
NGC 4494
NGC 4162
NGC 4747
NGC 4712
NGC 4725
7
18
22
8
23
NGC 4455
NGC 4032
COMA BERENICES
5
NGC 4158
NGC 5016
40
M64
NGC 4064
NGC4635
NGC 4561
39
NGC 4293
M85
NGC 4394
24
3
NGC 4340
NGC 4152
NGC 4450
NGC 4350
M100
25
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NGC4379
NGC4312
NGC 4262
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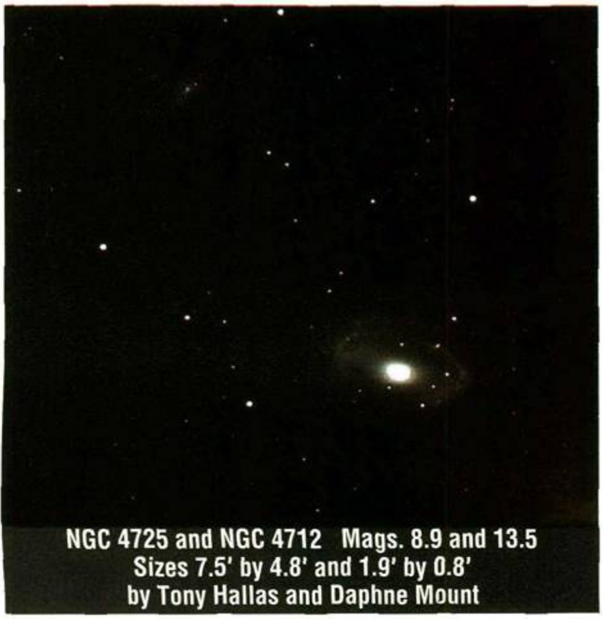


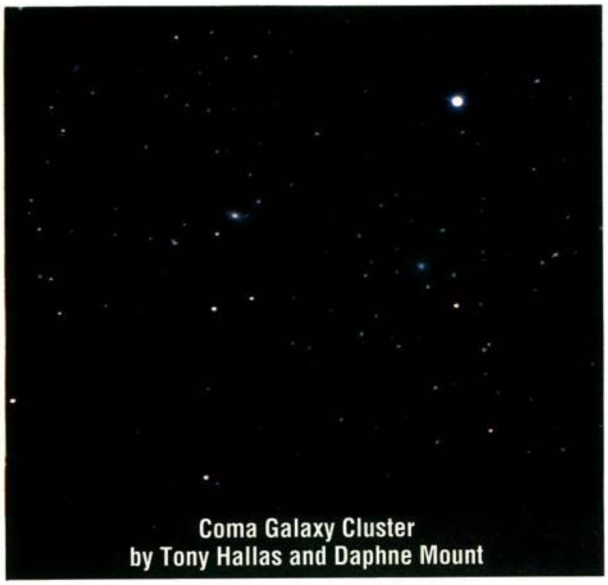
NGC 4725 and NGC 4712 Mags. 8.9 and 13.5
Sizes 7.5' by 4.8' and 1.9' by 0.8'
by Tony Hallas and Daphne Mount

ing 11' by 4.5'. NGC 4559 is a highly inclined Sc-type spiral galaxy with a very weak brightening toward the center. Otherwise, it is evenly illuminated across its surface. Three foreground stars are superimposed on this galaxy.

Located about 2° south of 31 Comae Berenices is **NGC 4725**. This magnitude 8.9 spiral has a weak bar-shaped hub, which in the galaxy classification scheme translates to a type S(B)b. This is a transition between barred spirals with a distinct bar-shaped hub and spirals with arms forming at various intervals around the disk. The photos of transitional barred spirals typically show arms emerging at various points along a bar-shaped central hub. A small telescope reveals a bright nuclear region in NGC 4725 surrounded by a mottled glow spanning 7.5' by 4.8'. A large telescope reveals more detail, including the galaxy's elongated hub and faint spiral structure.

NGC 4712 is located less than 15' west of NGC 4725, and both galaxies are visible in the same field of view. At magnitude 13.5, this compact, oval-shaped spiral galaxy requires a 10-inch telescope to be seen.

Coma Galaxy Cluster
by Joe Liddell


Coma Galaxy Cluster
by Tony Hallas and Daphne Mount

Deep-Sky Objects in Coma Berenices

Object	**R.A. (2000.0)**	**Dec.**	**Mag.**	**Size/Sep.**
Melotte 111	12h25m	+26°	1.8	275'
12 Com	12h22.5m	+25°51'	4.7, 8.5	12'
NGC 4448	12h28.2m	+28°37'	11.4	2.9' by 1.0'
17 Com	12h28.9m	+25°55'	5.4, 6.7	145'
NGC 4494	12h31.4m	+25°47'	9.9	4.8' by 3.8'
24 Com	12h35.1m	+18°23'	5.0, 6.5	20.3'
NGC 4559	12h36.0m	+27°58'	9.9	11' by 4.5'
NGC 4565	12h36.3m	+25°59'	10.2	15' by 1.1'
NGC 4712	12h49.6m	+25°28'	13.5	1.9' by 0.8'
NGC 4725	12h50.4m	+25°30'	8.9	7.5' by 4.8'
NGC 4747	12h51.8m	+25°47'	12.4	3.6' by 1.4'
NGC 4874	12h59.6m	+27°58'	11.9	2.7' by 2.7'
NGC 4889	13h00.1m	+27°59'	11.4	3.0' by 2.1'

Object: Designation in NGC or other catalog. **R.A. and Dec.:** Coordinates in equinox 2000.0. **Mag.:** V magnitude. **Size/Sep.:** Size in arcminutes or separation in arcseconds.

Smaller scopes (6 to 8 inches) may reveal NGC 4712, but only under very good skies. This 1.9' by 0.8' galaxy is a good test for moderate apertures. Also in the same field, **NGC 4747** can be found about 20' northeast of NGC 4725. This highly elongated galaxy is number 159 in Halton C. Arp's *Catalogue of Peculiar Galaxies.* Photographs reveal an edge-on, dusty galaxy that is presumably a spiral. There are several very faint plumes of galactic material splashed away from the disk. This may be the result of an interaction with another galaxy in the area. A large telescope reveals some mottled patterns of dust along the narrow disk of NGC 4747. The plumes themselves are beyond the reach of amateur instruments.

If you have a small telescope you'll find the next object challenging. The **Coma Berenices Galaxy Cluster** is a swarm of more than thirty faint galaxies visible in small telescopes. At 11th magnitude, **NGC 4889** is the cluster's brightest individual galaxy. As you peer into the eyepiece, consider that this 11th-magnitude smudge is the combined light of hundreds of billions of stars located over 425 million light-years away — some 20 times more distant than the Coma-Virgo cluster of galaxies. This object deserves at least a glance. Chances are, if your telescope can pick up NGC 4889, it will allow you to glimpse nearby **NGC 4874**, which is a half magnitude fainter.

NGC 4889 and 4874 are both giant elliptical galaxies surrounded by a swarm of smaller elliptical and lenticular galaxies. An 8-inch instrument reveals that NGC 4889 is elongated in an east-west direction. A 10-incher shows an oval glow with a brighter center. Larger telescopes allow you to see some (or all) of the thirteen other galaxies in the immediate vicinity of NGC 4889. As impressive as that sounds, you can see more if you slide on to NGC 4874. There, you will see a swarm of seventeen dimmer galaxies. Both fields are a must see for observers with 10-inch or larger scopes. Overlook this field of wonder and you are truly missing a grand view of the universe!

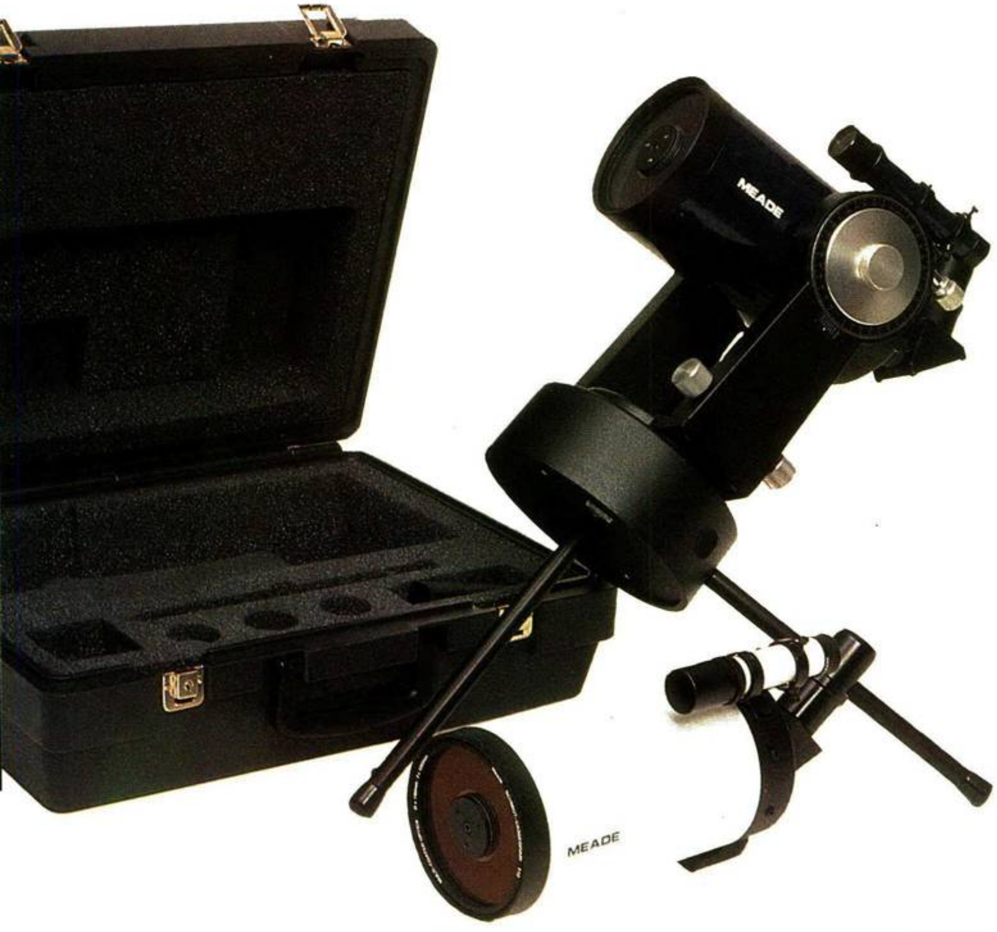
Whether you scan the objects in Coma Berenices from mere tens of light-years or hundreds of millions of light-years, each photon your eyes catch is a moment in our own Earth's history as well as the history of the universe. Starlight from members of the Coma star cluster began its journey before the American Revolution. The light of the Coma galaxy cluster dates back to the time in Earth's history when primitive plants and animals were the pinnacle of evolution. Imagine — all within the boundaries of a tiny, mild-mannered group of stars! ☐

Alan Goldstein is coordinator of Earth and natural sciences at Louisville's Museum of Science and History. He is also founder of the National Deep Sky Observers Society, a group of amateur astronomers dedicated to observing galaxies and clusters.

ASTRONOMY Tests the Meade 2045 Telescope

Looking for a compact, easy-to-use telescope? Despite some minor mechanical flaws, the Meade 2045 Schmidt-Cassegrain may be the one for you.

by Alan Dyer



Meade 2045D and 2045S

Manufacturer: Meade Instruments Corporation, 1675 Toronto Way, Costa Mesa, CA 92626, (714) 556-2291.

List Prices: 2045D Telescope: $1498; 2045S Spotting Scope: $998. Also available — Brass model 2045D: $3000; Chrome model 2045D: $1876.

Pros: Good optical and mechanical quality; very compact and convenient to use; standard Meade and Celestron visual and photographic accessories fit both scopes; optics are multi-coated.

Cons: Delay in drive motor engagement; shift in image when RA lock is engaged; small finderscopes; large tracking error in spur gear drive.

For many people, big telescopes are simply too much of a commitment, not only of cash but also of effort and storage space. For those who have a casual interest in the stars or who are just starting out, a small telescope (under 5 inches in aperture) is ideal. It is to this sizable chunk of the marketplace that Meade Instruments Corporation has aimed its 2045 Schmidt-Cassegrain telescopes.

The Meade 2045 is available in two versions: an astronomical telescope (the 12-pound Model 2045D) that comes with an equatorial fork mount and clock drive, and a tube-only spotting scope (the 5-pound Model 2045S). We tested a sample of each version, using units supplied by Meade that they assured us were off-the-shelf samples. Considering that the 2045D arrived with a loose right ascension knob, we felt confident that these were indeed random units and not pick-of-the-litter models.

Optical Quality

Schmidt-Cassegrain telescopes like the Meade 2045 use a combination of mirrors and a lens-like corrector plate to fold the long light-path of the scope into a very compact package. A conventional 4-inch refractor or Newtonian reflector with the same 1000mm focal length as the Meade 2045 would have a tube almost four feet long. Yet with a tube only 10 inches long, the 2045 provides the same light-gathering power and magnification of a conventional "full-length" telescope.

However, what's the resolution like? Are images as sharp? To help provide an answer, one night I set up the Meade 2045D telescope next to a $1000 apochromatic refractor of similar aperture, a VERNONscope 94mm Brandon telescope, whose optics we had previously tested as being first rate. On another night, I compared the Meade to a 76mm

Takahashi fluorite refractor whose tube assembly alone sells for $1400.

Compared to the images in the refractors, the Meade's planetary images (I used Saturn and Jupiter as test targets) were not quite as sharp or as contrasty. Nevertheless, the more affordable Meade stood up to the apo refractors very well, providing views that showed everything the more expensive refractors showed, but with slightly less "snap" — exactly what I would expect in a head-to-head comparison between a good Schmidt-Cassegrain and a top-notch refractor of comparable aperture.

On stars at high power, both the Meade 2045D telescope and the 2045S spotting scope showed stars as distinct Airy disks with surrounding diffraction rings, a sign that the optical quality is very good. (Poor optics can't show this classic diffraction pattern — they show stars as fuzzballs.) From examining both in-focus and out-of-focus images of real stars and an artificial test star, I would give the optics of both Meades a rating of B (with A being outstanding and E being unacceptably bad).

Nevertheless, in our experience a telescope with B optics will deliver images sharp enough to satisfy all but the most discerning observers. For example, both Meades easily split the close pairs of the double-double star Epsilon Lyrae and revealed multiple belts and structure in the clouds of Jupiter.

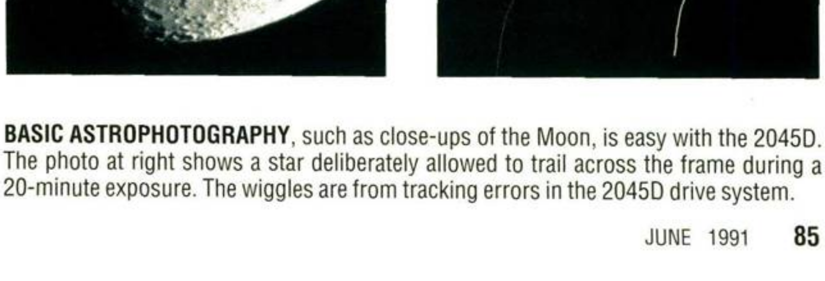
Mechanical Quality

Overall, I found the cosmetic finish of both models to be very good. The focusing mechanism, a common source of complaint in Schmidt-Cassegrains, was smooth and precise, with no slop or backlash and no shifting of the image as I focused.

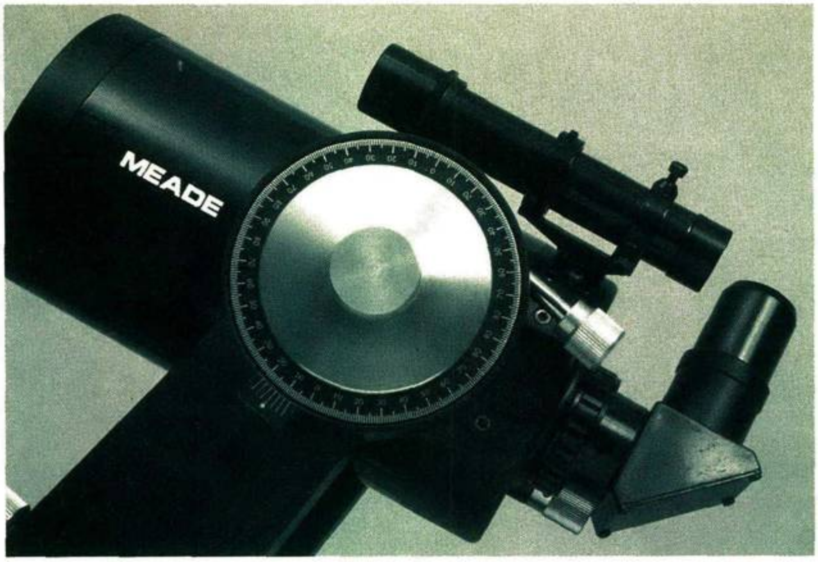
The finderscope on the 2045D is only a 5x24 unit, while the finder on the spotting scope is a 5x21. Although small, these proved to have good optical quality. Unlike the objective lenses of some small finders, these lenses were not stopped down by a mask hidden inside the finderscope, as is the deceptive practice on many cheap telescopes. The finders were solidly held in brackets with six alignment screws, an arrangement preferable to the single set of three screws used in some finderscope brackets.

The declination and right ascension (RA) lock knobs on the Model 2045D were effective, firmly locking the telescope into position, even with a heavy 35mm camera attached. However, on the 2045D the RA slow-motion knob fell off after a few minutes use. I tightened it back

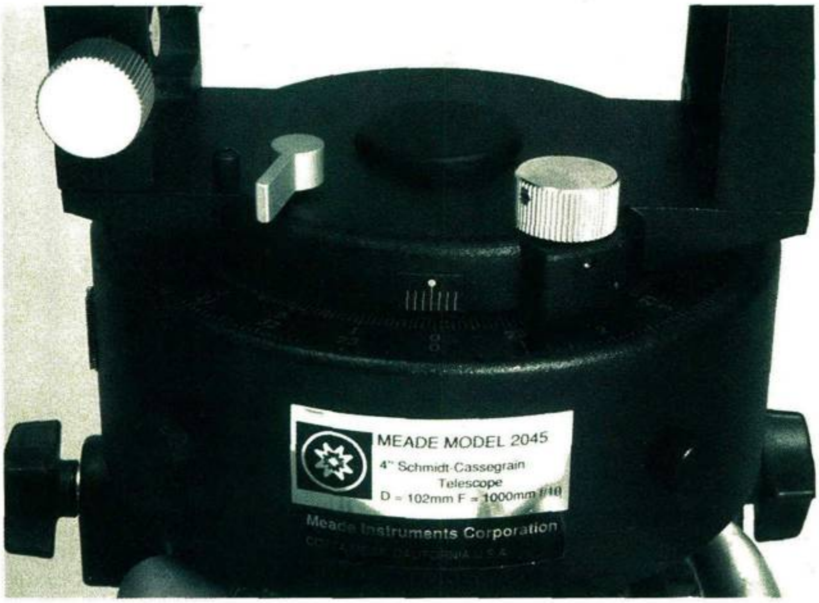
THE MEADE 2045D TELESCOPE can be attached to any tripod, though a solid unit like the Bogen model above is best, especially if you intend to take pictures through the telescope as shown below. Camera adapters are options with both models of the 2045.



BASIC ASTROPHOTOGRAPHY, such as close-ups of the Moon, is easy with the 2045D. The photo at right shows a star deliberately allowed to trail across the frame during a 20-minute exposure. The wiggles are from tracking errors in the 2045D drive system.



THE FINDER IS SMALL but the setting circles are large on the 2045D. A bigger 6x30 finderscope would be preferable but the 5x24 finder is adequate. Both versions of the 2045 use standard 1$^1/_4$-inch eyepieces, a plus for any small telescope.



FINE POSITIONING ADJUSTMENTS of the Meade 2045D are accomplished with the two slow-motion control knobs. The center lever is the RA lock. Note the lack of a serial number, something that should be standard on any premium optical equipment.

onto its shaft and had no further problems with it.

I did find another longer-lasting annoyance — on our test unit the drive motor of the 2045D didn't engage and start driving until about 50 seconds after the right ascension motion was locked. This delay made it difficult to center objects in the field of view. To do so, you must unlock the RA knob to slew the telescope. Once you have the object centered, you then lock the RA to engage the drive, but the 50-second delay, if typical of other units, means that at 200 power, an object will drift halfway across the field of view before the drive kicks in and stops the image drift. Meade suggested to us that the best technique is to always slew past an object and approach it from the east to take up the drive motor slack. However, we feel such "workarounds" shouldn't be necessary.

In addition, I found that as the RA knob is locked, the image shifts north in declination about one-quarter of a field diameter at 200x. Although these mechanical flaws are negligible at low power (25x to 80x), they become frustrating at higher magnifications.

Using a 2045

The 2045S spotting scope is as basic a telescope as you can get. It comes with an attached plate for adapting it to any tripod that employs a standard $^1/_4$-20 bolt. As with any high-power instrument (after all this is a 1000mm telephoto lens), a solid tripod is essential. Both instruments have threaded attachment points on the back end that accommodate any of the standard visual and photographic accessories for Meade and Celestron Schmidt-Cassegrains.

The 2045D telescope comes with a built-in DC pulse motor drive. It can be powered from a 10-AA-cell battery pack (included) or from a car battery or AC wall outlet using optional adapters. I like the DC motor, as it contributes to the portability of the 2045D. I found that the batteries lasted over 50 hours of continuous use at room temperature, better than Meade's more conservative estimate of 25 hours.

I tested the smoothness of the spur gear drive and found that there was an erratic tracking error of over 120 arc-seconds. This is quite high, but in all fairness the telescope is not intended for precision astrophotography. The drive accuracy is certainly good enough for lunar photography and for piggyback deep-sky shots, making the 2045D suitable for astrophotography dabblers.

The 2045D comes with a set of three legs that allow it to be placed on a table and tilted to aim at the Celestial Pole. The normal range of latitudes at which the telescope can be used in this fashion is from 25° to 50°. An optional shorter center leg allows it to be used at higher latitudes. For lower latitudes you would have to place the telescope on a solid tripod. Purchasing such a tripod isn't a necessity for using the 2045D telescope at other latitudes, but I would certainly recommend it. Compared to placing the telescope on a table, which may be shaky, a good tripod is more solid and makes it easier to get under the scope to sight through the straight-through finder.

The 2045S spotting scope can be purchased for about $500 from most dealers; the 2045D telescope for about $700. (The plastic carrying case is extra.) These prices are higher than those for most 4-inch Newtonian reflectors, but the difference buys you unsurpassed portability and convenience. Despite the minor mechanical annoyances we found, we can recommend both versions of the Meade 2045. Both would be fine starter scopes for general viewing. They would also make versatile second instruments or, considering that they will fit under an airplane seat, great telescopes to carry to next month's eclipse! ☐

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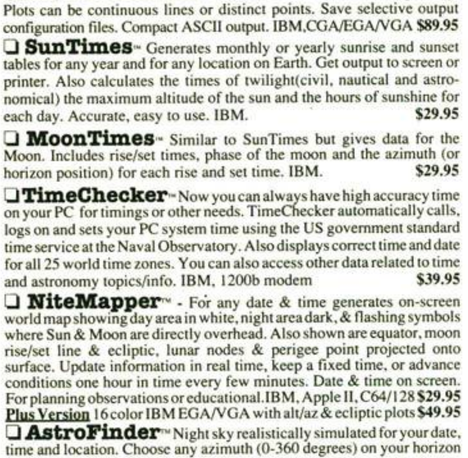

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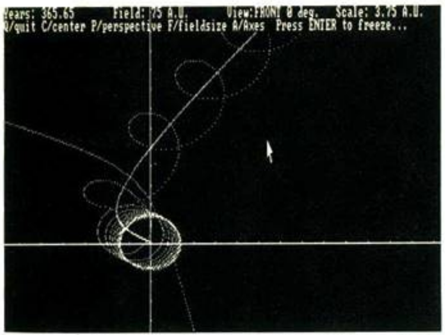

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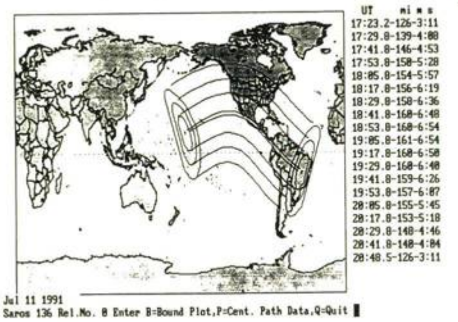

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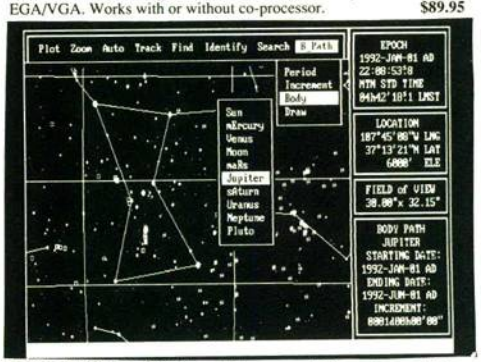

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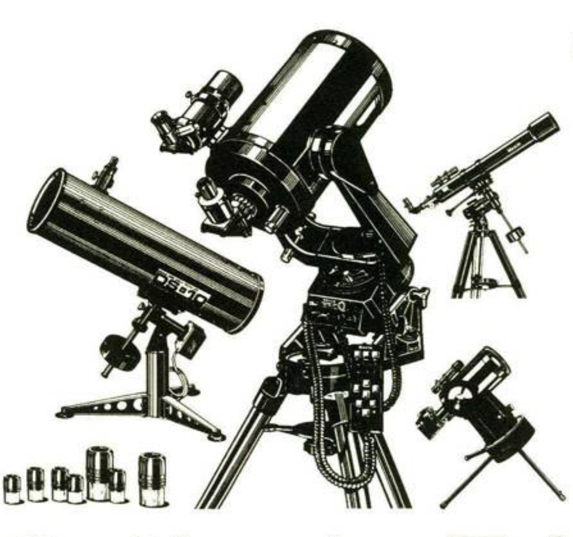

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SKETCHING MARS AT OPPOSITION

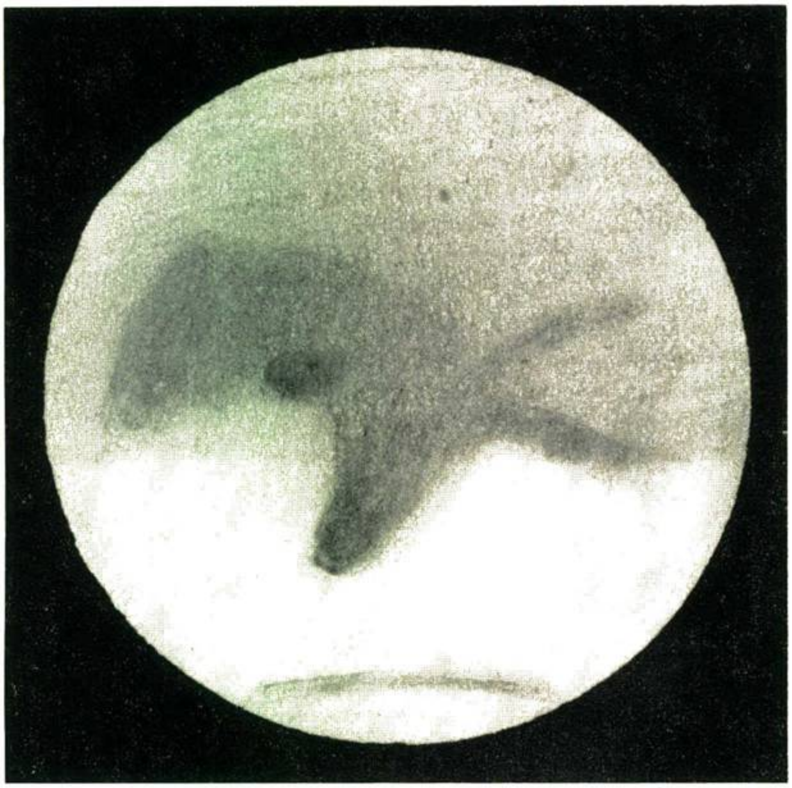
Half a year after its latest opposition in November, Mars was still the hottest planet in planetary observing. Because it offers so much detail visible in small telescopes, the Red Planet creates a wave of interest each time it looms large enough to be easily seen. Here are reader sketches and observations of Mars that did not fit in earlier issues.

- Fred W. Price, Buffalo, New York. "I've observed Mars since about a week or two before opposition using an 8-inch f/7 reflector. I typically use an 18mm Orthoscopic eyepiece and a 3x Barlow lens with an apodising screen to improve contrast and a Wratten #23A orange filter."

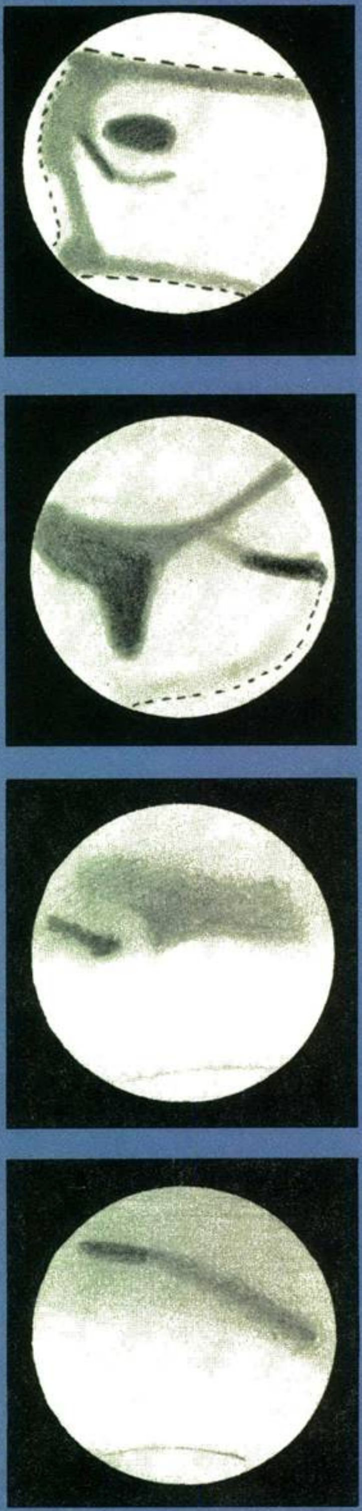
Martian observing brought surprises this year, according to Price. "I could not see the Hellas basin which was so prominent during the 1988 opposition. Also, the South Polar Cap disappeared before I began observing the planet but the North Polar Hood was as prominent as any time this year."

- Denis Fell, Wetaskiwin, Alberta, Canada. Fell used an 8-inch f/10 SCT at various magnifications and a #29 red filter for a wide range of Mars observations. As far back as September 1, 1990, he noticed that the North Polar area was very bright. During a period of extraordinary seeing on September 22, he suspected seeing the volcanoes around the Tharsis region. On October 20 he observed Electris and Zephyria as unusually bright and spotted faint dark markings near Olympus Mons. On November 18, Fell observed that Sabeus Sinus appeared unusually dark.

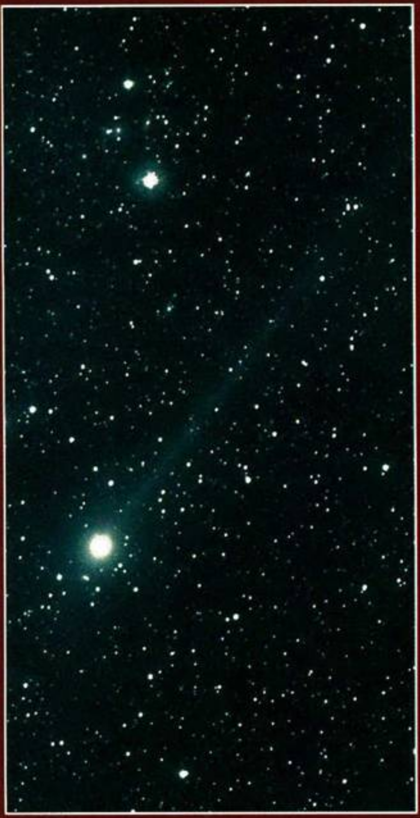
- Jose Olivarez, Wichita, Kansas. Olivarez used a 10-inch reflector at 171x and 245x. On December 10, 1990, he noted the striking appearance of the dark feature Solis Lacus, which dominated the planet's markings. A round, dark blob that covers a large area on the planet, Solis Lacus is popularly called the "Eye of Mars." — *David J. Eicher* ☐



MARS IN ALL ITS GLORY revealed to small telescopes last autumn prominent dark features such as Syrtis Major, Sinus Sabaeus, and Mare Serpentis. Sketch by Fred W. Price made with an 8-inch reflector at 224x.



THE CHANGING FACE OF MARS allowed amateurs to see a wide variety of features as the planet rotated and Martian regions altered in appearance. Most prominent were Solis Lacus (top), Syrtis Major (above center), Mare Erythraeum (below center), and Mare Cimmerium (bottom). Top sketches by Jose Olivarez; bottom sketches by Fred W. Price.



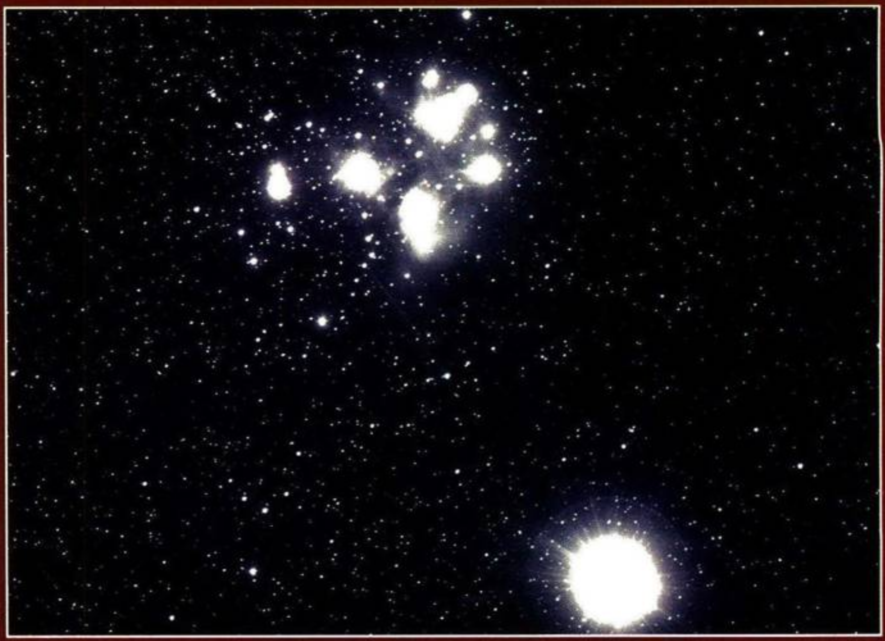
STRANGERS IN THE NIGHT

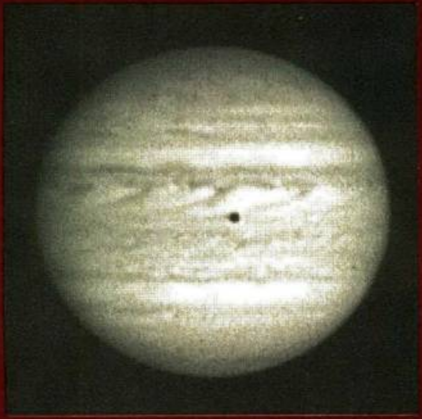
Twice in early 1991 bright planets passed close to bright, large, open star clusters. These celestial kisses between stars and planets are favorite subjects for astrophotographers, and their spectacular results are evidenced by reader submissions. Dazzlingly radiant Jupiter lay within 4° of the Beehive cluster in Cancer when Ronald E. Royer photographed the scene on January 11, 1991 (opposite page, top). When Joseph C. Petrillo captured the pair on February 3, Jupiter had begun to occult stars in the cluster (below, left).

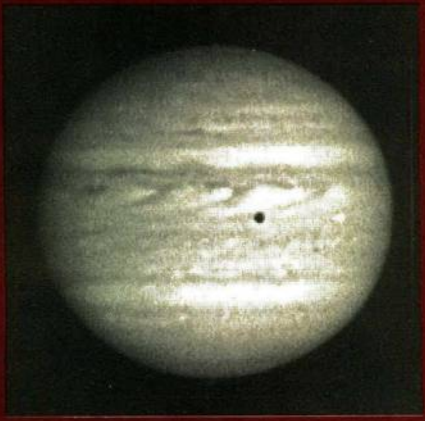
Not all astronomical artisans go after conventional images of Jupiter, however. Donald C. Parker used a 16-inch reflector and a SpectraSource Lynxx-PC CCD camera to record six frames of the planet and its moon Io in rotation. Richard Berry processed the images using ImagePro, a program specifically adapted for optimizing astronomical images. Taken together, the six frames constitute a rotation movie spanning 44 minutes on the evening of February 22, 1991.

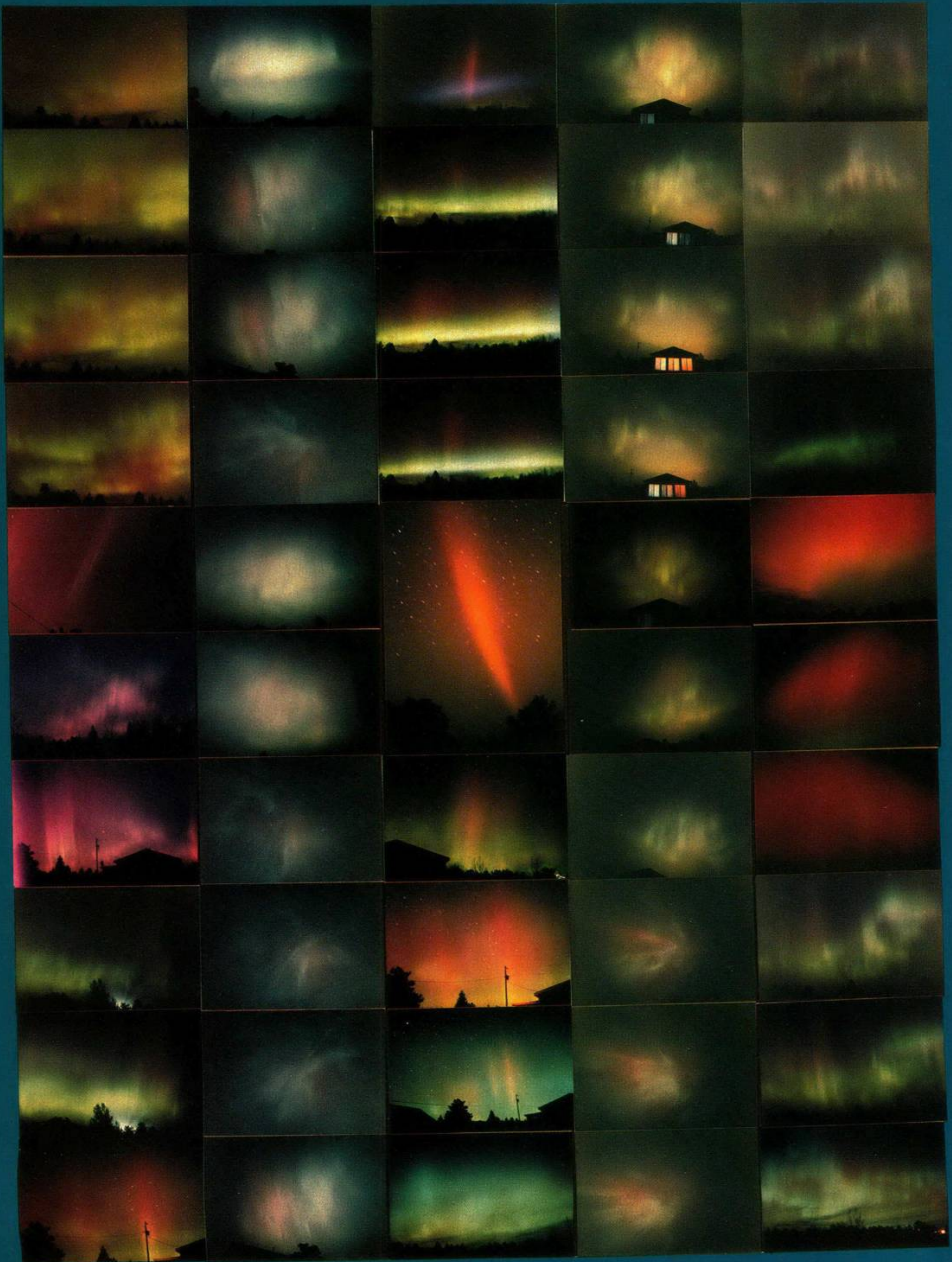
The other great close encounter involved ruddy Mars and the dipper-shaped Pleiades star cluster in Taurus. On January 10, 1991, Chris Schur recorded both objects as they lay less than 5° apart (below). Schur used a deep blue filter to suppress Mars and accentuate the nebulosity surrounding the Pleiades stars.

One of the rarest phenomena associated with comets is an anti-tail, a tail appearing to point toward the Sun rather than away from it. Chris Schur's photograph (left) of Comet Levy shows a prominent anti-tail as it appeared on February 9, 1991.









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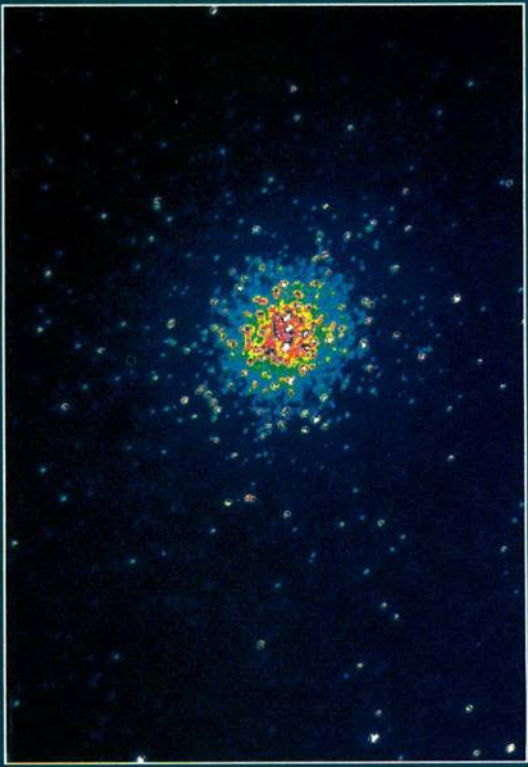
In addition to solar system objects, amateur astronomers have been busy photographing the realm of the deep-sky. George E. Fowler's portrait of globular cluster M14 was made with a 14-inch f/11 SCT and a Photometrics STAR-I CCD camera (right).

California astrophotographers Michael Stecker and James R. Foster achieved the near-impossible by capturing the faint supernova remnant S147 in Taurus (below right). Stecker and Foster pushed capabilities to the limit by exposing for 120 minutes on hypered Tech Pan film with an H-alpha filter.

The subtle reds and tangled structure of the Veil Nebula (NGC 6992-5), an enormous supernova remnant, are visible in an exquisite image by Bill and Sally Fletcher (below).

The smear of trees fixed in place, as Earth rotated the sky and the camera tracked the stars, is visible in Richard Andreassen's photograph of Canis Major (bottom). In this photo the brilliant star Sirius and, below it, star cluster M41 are the most prominent landmarks.



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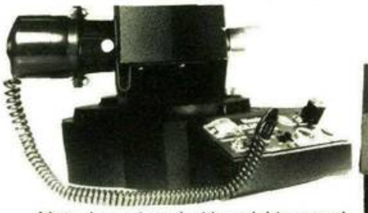

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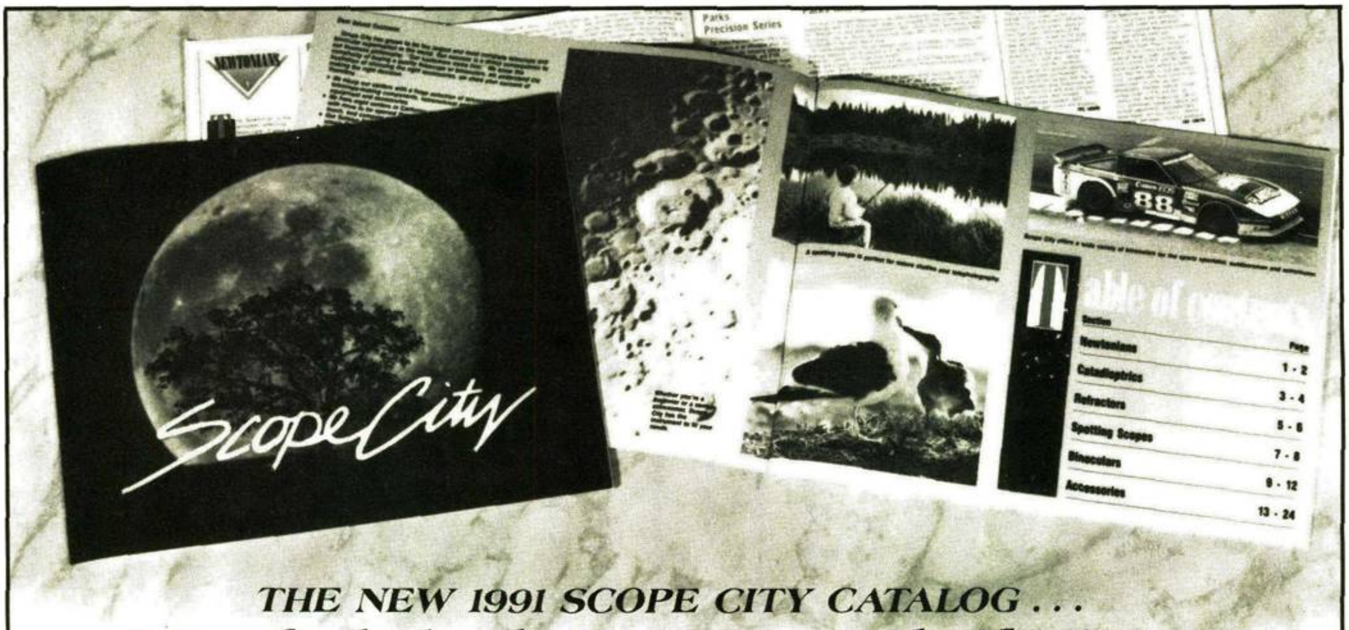

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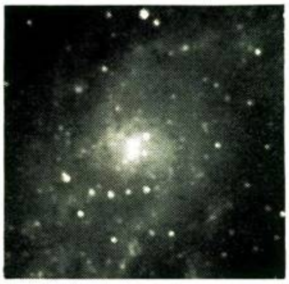

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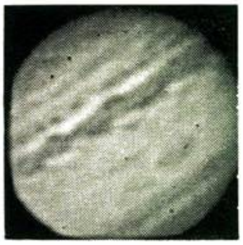

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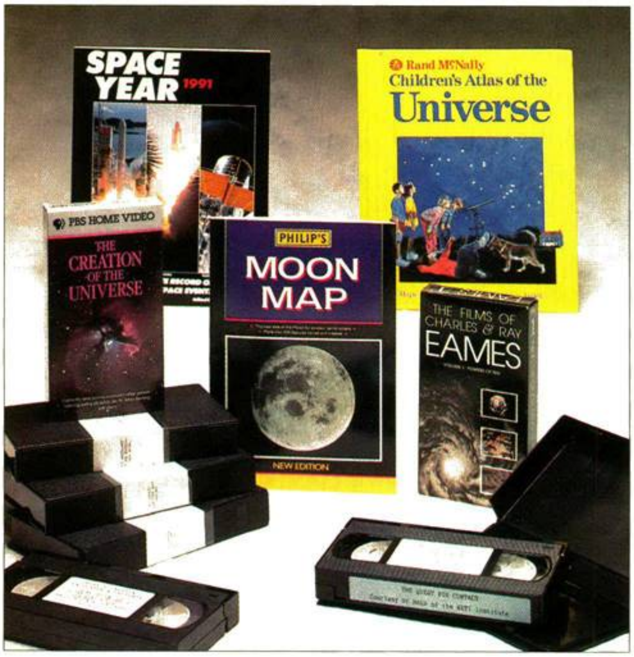
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The Astronomers, *PBS Home Video, distributed by Pacific Arts Video. Call (800) 222-5795 to order videocassettes for home and educational use. List price: $19.95 per 1-hour episode, $129.95 for boxed set of all 6 episodes. Also available at home video sales outlets.*

Most TV documentaries about astronomy and science never seem to get things right. Although their facts and figures may be accurate, they fail to evoke the emotional impact of the topic. They lose the sense of discovery and too often present their subject in a style resembling the most boring of college lectures. *The Astronomers,* the new PBS-TV series and home video set, isn't like that. *The Astronomers* is a series that gets things right.

Over the course of its 6 hour-long episodes, *The Astronomers* provides an unprecedented look at how the process of scientific discovery works. It successfully contrasts visions of grand cosmic mysteries with insights into the daily lives of the visionaries. Over the course of the series, we're allowed to peer over the shoulders of astronomers as they plan their research and carry out their observations. Very few science documentaries have provided such an intimate view of the inner workings of science.

Unlike the "talking head" approach of many documentaries, in *The Astronomers* the scientists become personalities. They are allowed to express their thoughts and feelings and not just spout facts and figures. This emotional appeal is enhanced by a judicious blend of music behind key scenes. The original score by composer J. A. C. Redford incorporates an effective main theme that Redford uses throughout the series in many variations. Few science documentaries make appropriate use of music — perhaps producers feel it distracts from the hard information they're trying to impart. I'm glad *The Astronomers'* creative team didn't fall into that traditional thinking.

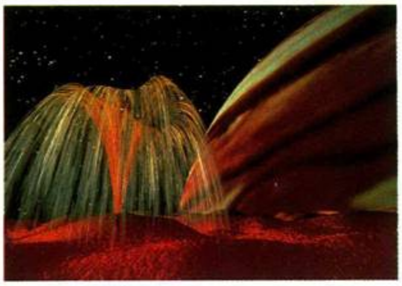
I was also pleased to see the use of dramatic, often surprising transitions, another tool for maintaining viewer interest that few documentaries exploit. For example, in episode one computer animation of a gravitational lens cuts quickly to a performance of Chilean street musicians, which then leads into a visit to one of the Chilean observatories. Hard cuts like that intermix with softer blends from scene to scene, providing a varied pace to the programs.

Besides profiling astronomers from five continents, *The Astronomers* has also been careful to represent astronomers of both sexes and from various minority groups throughout the programs. Since a major audience for *The Astronomers* will be students, the producers wanted the "stars" of the series to be inspiring role models for kids of all backgrounds. They have done so very effectively. Indeed, for this reason alone, *The Astronomers* is recommended viewing for all science students, even if astronomy, as is often so sadly the case, is not in the local curriculum.

Educators should be aware, however, that *The Astronomers* is not a TV textbook on astronomy. Each episode focuses on a single "hot topic" in astronomy, one with wide "gee-whiz" appeal. These include, in order from episode one through six: dark matter, black holes, the Big Bang, gravity waves, supernovae, and the search for planets around other stars. While grand in its sweep, the series does not attempt to act as a tour of the universe. This may be frustrating to some viewers who may get the feeling the series is leaving out a lot. They may have preferred to see less time devoted to the astronomers and more to the astronomy itself. Educators won't be able to use the series as a substitute for a traditional astronomy course. It serves instead as a motivating enrichment to standard classroom presentations.

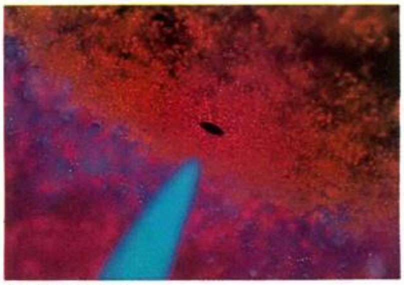
Adding to the series' appeal are the high production values the producers have employed throughout: aerial shots, dramatic interior lighting of observatories, and simply taking the time to follow research projects from beginning to end. For example, episode three's profile of the race between the rocket-borne experiment of Andrew Lange and Paul Richards and the launch of the Cosmic Background Explorer (COBE) satellite under the leadership of John Mather illustrates the competitiveness of science. When the results come in and Mather's COBE data disproves Lange and Richards' research, we also see how even the best-executed experiments can lose out.

The productions also make extensive use of computer-generated animation of celestial objects. These are the best astronomical special effects created for a documentary since Carl Sagan's *Cosmos* and NASA's 1970s reworking of the classic



The surface of Jupiter's moon Io

The rings of Saturn



A black hole

SCENES FROM A SERIES illustrate some of the computer-generated special effects sequences created for *The Astronomers*. Images © Kleiser-Walczak.

National Film Board of Canada's *Universe*. I was particularly impressed with the sequences illustrating the wall of distant blue galaxies, the zoom out from a black hole, the colliding galaxies sequence, and the flight through the Milky Way. They all provide clear visions of otherwise difficult concepts and are just plain wonderful to look at as well.

Viewers well-read in the science will also find lots of information throughout the series they won't have encountered before. For example, details on projects such as the proposed Laser Interferometry Gravitational-Wave Observatory (which figures prominently in episode four) will be new to most people. But, for the benefit of the uninitiated, the series would have done well to incorporate more basic information. Many viewers, for example, may be lost by the discussions of dark matter and the cosmic background radiation.

Other criticisms of the series are minor. *The Astronomers* contains two obvious technical flaws that TV producers often get wrong: the image used in episode one to represent the Moon as seen through a backyard telescope is actually an Apollo photo of the Moon's farside, and the Apollo shot of Earth in episode three is flipped over as a mirror image.

In addition, some episodes have what I consider to be a flawed structure — programs seem to come to an end before they do. Near the end of episode one, for example, the program returns to telescope-maker John Dobson (who was featured at the opening of the show), surrounded by enthusiastic students commenting on their first looks through their new telescopes. This seems to be the emotional climax of the show, but then the program switches back to continue with nuts and bolts explanations of the nature of dark matter.

A similar false ending occurs in episode six, during which the Voyager/Neptune encounter provides what seems like a natural climax. If the program had then switched to scenes of amateur astronomers excitedly exploring the night sky it would have made an inspiring ending, combining the excitement of "big science" with the thrill of personal, backyard science. Instead, the program goes on to talk about the mundane task of naming features on Neptune's moon, Triton.

If there's any significant criticism I could level at *The Astronomers*, it is that it should have paid more attention to amateur astronomers. By showing more examples of backyard astronomy, *The Astronomers* could have better succeeded in showing astronomy as a science *you* can do, and not just as the pursuit of a select few. The series then could have shown that the same joy of discovery it so well captures among the elite teams of researchers can be shared by anyone with a telescope and a clear night sky — indeed, just a clear night sky!

However, the outstanding features of *The Astronomers* far outweigh its shortcomings. It is a series all of ASTRONOMY's readers will want to watch, either as it is broadcast on PBS stations or on home videocassette. To quote John Dobson, whom the series' writers so aptly describe as the carny-barker for the cosmos, "Everybody is born curious. Everybody wants to see this universe. Everybody wants to understand this universe. They're just waiting for someone to present it to them." *The Astronomers* does just that. — *Alan Dyer* ☐

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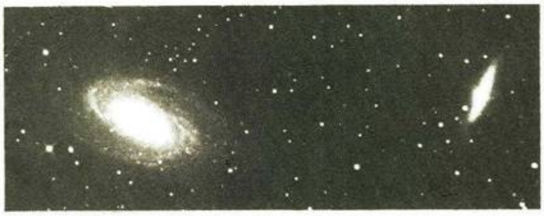

Galaxies M81 (left) and M82 (right) in Ursa Major. 30 minute exposure by Martin Germano using 103aF, and an 8" f/5 telescope with a LUMICON 2" Newtonian EASY-GUIDER. Visually M82 shows much mottling and detail. Spiral detail in M81 is hard to see visually.

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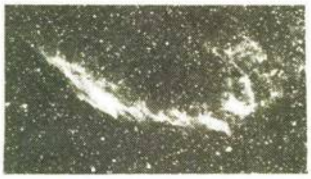

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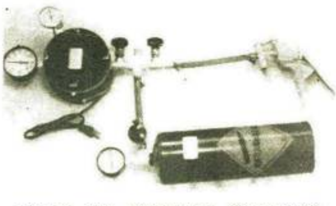

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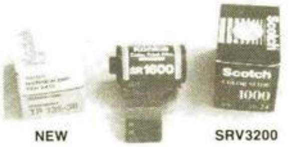

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- 4000 pulse (0.09° accuracy) high resolution encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, date, sidereal time, etc.
- 9V Battery lasts many nights.

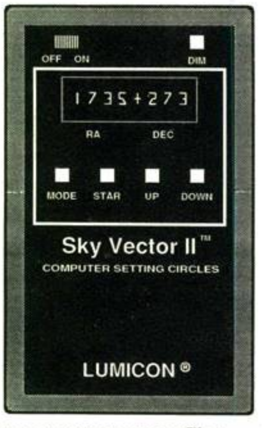
Each LUMICON SKY VECTOR™ includes one computer with digital readout, two precision high resolution digital shaft encoders, connecting cables, & *mounting* hardware (for most popular telescopes). **Specify telescope.**

LUMICON SKY VECTOR™ for Meade 2080, Meade 2120 *(Specify)*	**$399**
For Celestron C-8, C-11 *(Specify)*	**$399**
For Coulter Odyssey 8", 10", 13", 17½"	**$399**
For any alt-azimuth (Dobsonian) scope	**$399**
For Celestron C-14 (rewire dec. motor)	**$498**
SKY VECTOR KIT (for skilled ATM's)	**$369**

Reference catalogues (1000's of objects)

Burnham's *Celestial Handbook*, I, II, III	**$36.85**
Revised New General Catalogue (all NGC and IC, Epoch 1975.0)	**$35.00**
Sky Catalogue 2000.0, Vol. II	**$29.95**

Only the LUMICON SKY VECTOR II has size, true **visual** magnitude, and complete **visual** appearance description for **all** 1500 objects in memory.



LUMICON SKY VECTOR II™ Computer with 1500 object memory, digital readout of coordinates, easy-to-use controls, object size, visual magnitude and visual appearance descriptions.

Please specify telescope type:

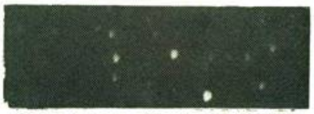
LUMICON SKY VECTOR II™ for Meade 2080, Meade 2120 (*Please specify)*	**$589**
For Celestron C-8, C-11 *(Specify)*	**$589**
For Celestron C-14 (rewire dec. motor)	**$665**
For Coulter Odyssey 8",10",13"17½"	**$589**
For any alt-azimuth (Dobsonian) scope	**$589**
SKY VECTOR II (upgrade, computer only)	**$395**

The **LUMICON SKY VECTOR II™** has all the features of the regular SKY VECTOR, but has 1500 of the best deep-sky objects in memory, selected by noted observer Steve Gottlieb, along with their coordinates, size, true visual magnitude, and other descriptive data. The sophisticated computer programming also will guide you to the object selected by displaying the real-time angular separation. Just move the telescope until the angles displayed become "0" using the "GUIDE" mode.

LUMICON SKY VECTOR II FEATURES:

- Includes **size, true visual magnitude & complete visual appearance description** for all 1500 objects
- All 110 Messier objects
- Brightest 31 alignment stars
- User definable catalogue of 25 objects retained in memory
- 703 galaxies, groups & clusters
- 228 best open star clusters
- 170 best planetary nebulae
- 77 emission & reflection nebulae
- 10 best dark nebulae
- 107 best gobular star clusters
- 205 best colored & multiple stars
- Displays Uranometria 2000.0 chart no.
- ROM upgradable for planets, extended object lists, etc.
- TIMER function, elapsed time & stop watch
- 2 star alignment for alt-azimuth or equatorial telescope systems
- 1 star alignment if polar aligned
- Uses Epoch 2000.0 coordinates
- May align on any of the 1500 objects in memory

COMA CORRECTOR



Coma 1 inch off-axis 17½" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces. Clear aperture = 1.8".

LUMICON Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7	**$85.00**
2" Adapter for Hasselblad	**$185.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

MEADE® TELESCOPES

LUMICON, 2111 Research Dr., #5, Livermore, CA 94550
(415) 447-9570
FAX (415) 447-9589

LUMICON ACCESSORIES

NEW PREMIER SERIES TELESCOPES

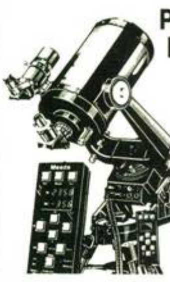
All Meade Premier Series telescopes **include Smart Drive (SD) permanent periodic error correction**, multi-coated enhanced optics (MCOG), Electronic Command Center (ECC), and **include** advanced LX6 all-electronic drive system. Select f/10 or f/6 optics, and select only the optional features you **need.** The 8" has a 6X30 finderscope and the 10" has an 8X50 finderscope. SD = Smart Drive.

2080 Model 40SD, 8" f/10	**$1650**
2080 Model 46SD, 8" f/6	**$1799**
2120 Model 40SD, 10" f/10	**$2099**
2120 Model 46SD, 10" f/6	**$2298**
Model 2600 16" f/10	**$9950**

Options Enhance Performance

Super Wedge for 10"	**Add $299**
ECC Electronic Command Center	**$275**
#39 Declination motor	**Add $109**
Digital setting circle	**Add $399**
2" Star diagonal	**Add $179**
LUMICON Cassegrain Easy-Guider *(Please specify camera)*	**Add $225**
LUMICON Giant Easy-Guider (for #40) *(Specify camera)*	**Add $395**
LUMICON Giant Easy-Guider (for #46) *(Specify camera)*	**Add $295**

PREMIER 2080 MODEL 50SD $1950



Meade Premier 2080 Model 50SD

MEADE SERIES 4000 EYEPIECES

Super Plossl: 6.4mm, 9.7mm, 12.4mm **$89** 15mm, 20mm, 26mm **$89;** 32mm **$109**
Super Wide-angle: 13.8mm **$129,** 18mm **$135,** 24.5mm **$149,** 32mm (2") **$219**
Ultra Wide-angle: 4.7mm **$149,** 6.7mm **$179,** 8.8mm **$209,** 14mm **$249**

SCHMIDT-CASSEGRAIN

2045D 4" f/10 w/motor drive	**$695**
2080A Standard 8" f/10 w/tripod	**$999**
2080B Std. w/tripod, MCOG	**$1099**
2080 Model 50SD, 8" f/10	**$1950**
2120 Model 50SD, 10" f/10	**$2399**
2120 Model 50SDH, 10" f/10 w/Super Wedge, Smart Drive	**$2698**
2080 Model 56SD, 8" f/6.3	**$2099**
2120 Model 56SD, 10" f/6.3	**$2595**
2120 Model 56SDH, 10" f/6.3 w/Super Wedge, Smart Drive	**$2894**
Dew shield - essential! 8" **$119;** 10"	**$129**
LUMICON EASY-GUIDER for 2080	**$225**
EASY-GUIDER (f/4-f/10) for 2120	**$395**
CAT command control, 8200 objects	**$999**

SCHMIDT-NEWTONIAN

MTS-SN6, 6" f/5, #788 drive	**$649**
MTS-SN6 w/drive, MCOG	**$698**
MTS-SN8, 8" f/4 w/drive, MCOG	**$795**
#36 LX3 hand cntrl. & #38 dec. motor	**$189**

NEWTONIAN

Model 826C 8" f/6 w/motor, 2" focuser	**$898**

SPECIAL PROMOTION

Model DS-10A, 10" f/4.5 with motor, 2" focuser	**$775**
Model DS-16AB, 16" f/4.5 w/motor, 2" focuser, Sealmaster ball bearings	**$1875**
8X50mm finderscope w/brackets for DS-10 or DS-16	**$109**

2" DELUXE BARLOW

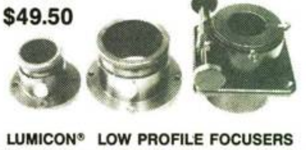
1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. Guide-stars also become much sharper to make guiding easier. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.8x multiplier lens	**$235.00**

NEW! LOW PROFILE HELICAL FOCUSERS

FROM $49.50



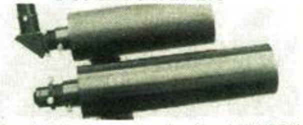
LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	**$49.50**
LUMICON 2" Helical Focuser 1½" high	**$59.50**
LUMICON Non-rotating Helical Focuser	**$89.50**
2" rack & pinion focuser, only 2" high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™



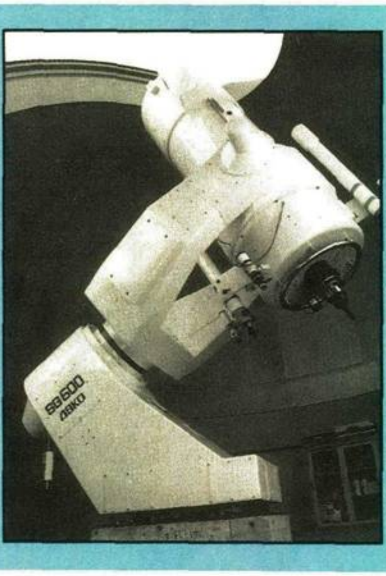
Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra. The

1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle 80mm SUPER-FINDER	**$179.50**
1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$39**
1¼" Star Diagonal **$39**, Mounting Brackets,	**$37**
1¼" Amici Prism diag. for correct left-right views	**$69.50**

2" ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

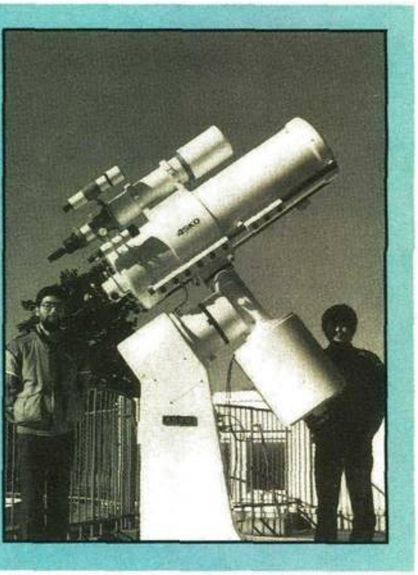
2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-90F, C-100F	**$39.50**
2" Accessory adapter for Comet Catcher, C-6, Meade 310, 320 refractor	**$30.00**
2" adapter for Takahashi E-130, 160	**$59.50**



1 New RVR/ASKO Observatory Telescopes

The ASKO Manufacturing Company of Japan is offering two new observatory-class instruments: a 15.25-inch Cassegrain and a 23.6-inch Newtonian/Cassegrain. Both are available on a world-wide basis exclusively through R.V.R. Optical. R.V.R. also offers a complete line of custom-built telescopes up to 40 inches in aperture, a line of Schmidt-Cassegrain telescopes up to 23.6 inches, and Schmidt cameras and photo-visual Wright Schmidt cameras up to 20 inches in aperture.

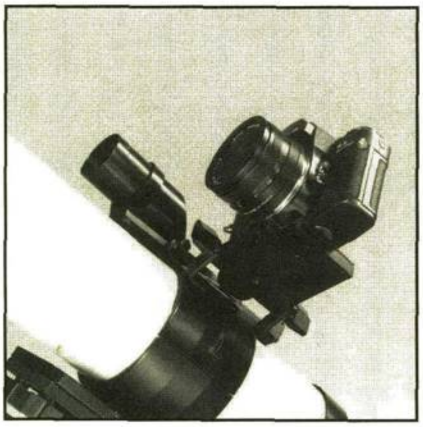
R.V.R. Optical, P.O. Box 62, Eastchester, NY 10709, (914) 337-4085. Send $5 ($10 for foreign orders) for complete information package.



2 Piggy-Cam Camera Bracket

This is a mount for attaching a 35mm camera to the side of a Tele Vue Genesis or Renaissance telescope for piggyback astrophotography. Piggy-Cam has a $^3/_8$-inch thick aluminum mount plate that can be adjusted and locked to place the camera at almost any desired angle over a sweep of 180°. Piggy-Cam will store in the Genesis/Renaissance case without removal from the telescope. It can also be retrofitted to other Tele Vue telescopes of any vintage.

Tele Vue Optics, Inc., 20 Dexter Plaza, Pearl River, NY 10965, (914) 735-4044, FAX: (914) 735-4112. $65.



3 Minolta Autofocus Binoculars

Minolta has announced the first continuous autofocusing binoculars, said to eliminate the effects of eyestrain associated with "permanent focus" types. The autofocus models use a contrast-sensitive optical sensor and microcomputer to control an internal stepping motor which focuses the objective lenses. Minolta autofocus binoculars are available in two models, an 8x22 and a 10x25. Both are roof prism designs.

Minolta Corporation, 101 Williams Drive, Ramsey, New Jersey 07446, (201) 825-4000. 8x22 model: $376, 10x25 model: $421.

4 New Videos From Roger W. Tuthill, Inc.

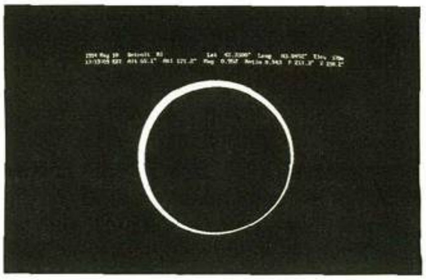
Tuthill is now offering a new VHS-format videotape that features demo images taken with the Tuthill low-light-level (0.02 lux) Star Trap video camera. Sequences include 1989's occultation of the star 28 Sagittarii by Saturn, as well as Sun, Moon, and planet images. Also available: a VHS-format videotape that demonstrates the basics of using a Schmidt-Cassegrain telescope and an instructional tape on the basics of astrophotography.

Roger W. Tuthill, Inc., Box 1086-A, Mountainside, NJ 07092, (800) 223-1063. Star Trap Demo Video: $25, Schmidt-Cassegrain Basics: $50, Astrophotography Basics: $50, Latter two together: $80.

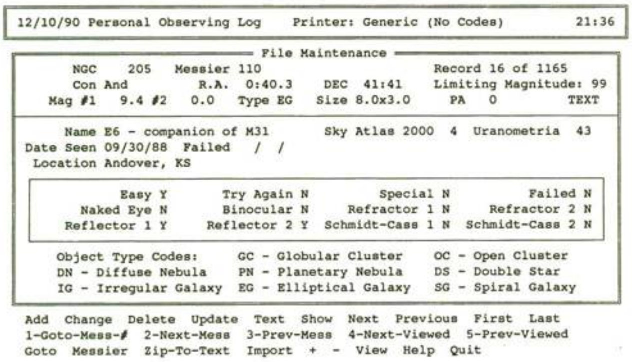
5 EclipseLive

EclipseLive computes information about solar eclipses, including dates and the types of eclipses and times of eclipse events for any desired location on Earth. The program will accurately display the eclipse as seen from a specified location, either in real-time or in time-lapse mode. Additional options allow you to calculate the centerline and north and south limits of the path, shadow position according to longitude, and the outline of the umbral/penumbral shadow. EclipseLive is published by the author.

Andrew Lowe, 4939 Vantage Crescent N.W., Calgary, Alberta, Canada T3A 1X6. $39.95 (postage paid). For IBM and compatible computers.



6 Personal Observation Log Software



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12/10/90 Personal Observing Log    Printer: Generic (No Codes)         21:36

                     ═══════════ File Maintenance ═══════════
      NGC    205   Messier 110                          Record 16 of 1165
      Con And          R.A.  0:40.3   DEC  41:41   Limiting Magnitude: 99
   Mag #1   9.4 #2   0.0   Type EG   Size 8.0x3.0     PA   0          TEXT

     Name E6 - companion of M31        Sky Atlas 2000  4  Uranometria  43
 Date Seen 09/30/88  Failed   /  /
  Location Andover, KS

            Easy Y        Try Again N          Special N          Failed N
       Naked Eye N        Binocular N      Refractor 1 N      Refractor 2 N
     Reflector 1 Y      Reflector 2 Y  Schmidt-Cass 1 N  Schmidt-Cass 2 N

     Object Type Codes:      GC - Globular Cluster    OC - Open Cluster
     DN - Diffuse Nebula     PN - Planetary Nebula    DS - Double Star
     IG - Irregular Galaxy   EG - Elliptical Galaxy   SG - Spiral Galaxy

 Add  Change  Delete  Update  Text  Show  Next  Previous  First  Last
 1-Goto-Mess-#  2-Next-Mess  3-Prev-Mess  4-Next-Viewed  5-Prev-Viewed
 Goto  Messier  Zip-To-Text  Import  +  -  View  Help  Quit
```

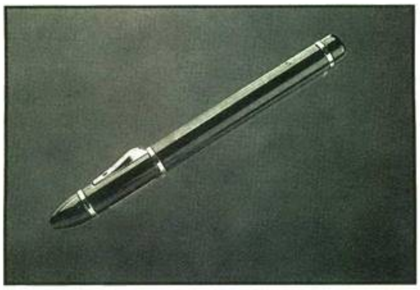
The POL package comes with a database of 1,150 objects and allows you to add your own objects. It can produce 31 different reports that can be viewed on screen, printed, or copied to a text file. You can restrict by any field what objects are shown on-line and in reports. You may also enter up to 32,000 characters of observational notes for each object. A 40-page manual accompanies the software.

Ohio Star Software, 15 Graywood Court, Centerville, OH 45458, (513) 434-2810. Individual license: $30; Club license: $75. Demo disk available for $3. For IBM and compatible computers.

7 EMPHASIS Laser Pointer

These pointers use laser diode technology to project a red dot which can be seen in normal room lighting at ranges up to 150 feet and against a lit projector screen. Suitable for clubs to use at meetings and public lectures, the pointers are housed in cases of brass and aluminum. The Executive model features a black-anodized case with 24kt gold trim. The Professional is anodized a light gray with black trim. Both models are 8½-inches long and weigh 5½ ounces with two AA batteries installed.

The Layman's Laser Company, P. O. Box 58770, Seattle, WA 98138-1770, (800) 258-2202. Professional: $219; Executive: $249.



8 Supercool Photomultiplier Chamber

The TE 329RF "supercool" PMT chamber is designed to bring side-window photomultiplier tubes (used in photoelectric photometry) down to a stable temperature of –50° C or lower to reduce current "noise." The chamber uses virtually any liquid cooling medium. The TE 329RF accepts 1-inch or 30mm diameter tubes and features a "no dew" heating system to ensure a clear view into the chamber through its Plexiglas window.

Products for Research, 88 Holten Street, Danvers, MA, (508) 774-3250. Write for performance and price information. ☐

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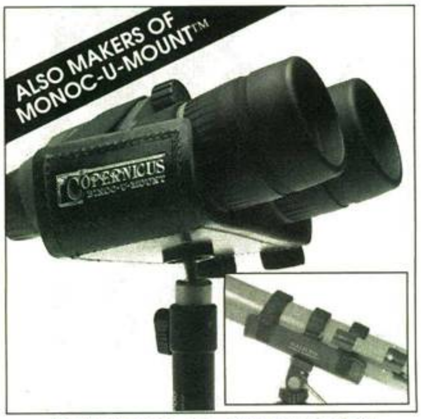

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Meade

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2080 LX5SP F/10

A FOCUS CAMERA EXCLUSIVE PACKAGE!

We've taken Meade's 2080 LX5 8 inch Schmidt-Cassegrain telescope & upgraded it! Just look at the features....

- *World famous 8 inch 2000mm F/10 optics with Meade MCOG multi-coatings*
- *Quartz controlled LX5 drive system opertaes from AC, DC or AA batteries & features 2X & 8X scanning speeds*
- *Meade 25mm (80X) & 9mm (220X) MA eyepieces*
- *LX5 ECC hand controller for easy operation*
- *JMI Motodec DEC motor with variable speed*
- *6x30 finderscope · Wedge & Tripod · Trunk case*

VERY LIMITED SUPPLY
List Price Over $3000 **\$1159^{95}**

DIGITAL SETTING CIRCLES FOR 2080 LX5
*purchase with telescope & save $50 .... only **$349***

PREMIER 2120/30 **WOW!**

10" SCHMIDT-CASSEGRAIN

Never has so much telescope cost so little! This is positivly the last chance to get a fully equipped Meade 10" Schmidt-Cassegrain at this price.

COMPLETE FACTORY PACKAGE INCLUDES:
10 inch 2500mm F/10 optical tube, microprocessor controlled LX6 drive system, 25mm MA eyepiece, 8x50 finderscope, 1¼" diagonal, AC adapter DC battery pack, case wedge & tripod **$1599**

2045D

THE SCHMIDT-CASSEGRAIN YOU CAN TRUELY TAKE ANYWHERE

4 inch 1000mm F/10 optical tube with MCOG multicoatings, equatorial fork mount with reversible DC motor drive & table tripod, 5x24 finder, 1¼" star diagonal, 25mm eyepiece, AA battery pack **$607**
Meade List Price Over $1400

Case for 2045D **68.95** Tripod & Wedge **235**
NEW 2045 Designer Series Telescopes .... **CALL**

2080 BASIC

8 inch 2032mm F/10 Schmidt Cassegrain optics equatorial fork mount with motor drive, **wedge, tripod,** 6x30 finder, 1¼" diagonal,25mm eyepiece. **$929**
Meade List Price Over $1700

2080 BASIC MCOG .... CALL

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50 F/10	**CALL**	**2087**
56 F/6.3 ***SPECIAL***	**1699**	**2149**
50 SD F/10 **Smart Drive**	**1817**	**2267**
56 SD F/6.3 **Smart Drive** ..	**1967**	**2389**
70 SD F/10 **Smart Drive**	**CALL**	**CALL**
76 F/6..3	--	**3799**
76 SD F/6.3 **Smart Drive** ..	**CALL**	**CALL**

Super Wedge option for 2120 Premiers **219.95**
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The world's finest wide field Schmidt Cassegrain Telescopes - so good even **NASA** uses them! Get a 59% wider field of view & a 60% reduction in photo exposure times than with a traditional 8" SC Telescope. Meade now has a F/6.3 wide-field scope to fit any requirement and budget.

2080 LX5SP F/6.3

The most affordable of Meade's 8 inch F/6.3 Schmidt Cassegrain Telescopes. This complete package includes Quartz microprocessor controlled LX5 drive system with hand controller, 26mm Super Plossl eyepiece, 6x30 finder, 1¼" diagonal, wedge, tripod & case **$1087**
VERY LIMITED SUPPLY

PREMIER 2080/56

Meade's renowned 1200mm F/6.3 8 inch 1200mm F/6.3 optical tube matched to an ultra,-precise LX6 drive system and supplied with ECC hand controller, DEC motor, 26mm Super Plossl eyepiece, 9x60 RA polar illuminated finder, 2" diagonal, wedge, tripod & case **$1699**
Meade List Price Over $00

PREMIER 2120/56

Meade's 1600mm F/6.3 10 inch 1200mm F/6.3 optical tube privides 25% more light gathering than a comparable 8 inch tube. Add to that an ultra, precise LX6 drive system and supplied with ECC hand controller, DEC motor, 26mm Super Plossl eyepiece, 9x60 RA polar illuminated finder, 2" diagonal, wedge, tripod & case & you have the best value in a large aperture wide field telescope. **$2149**
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Meade 312

ALT-AZIMUTH

The Meade 323 3.1" Alt-Azimuth Refractor is ideal for high magnification planetary observation.

COMPLETE PACKAGE INCLUDES:
3.1 inch 900mm F/11 optical tube, Alt-Azimuth mount with slow motion controls, 25mm MA eyepiece, 5x24 finder, 1¼" diagonal, field tripod & much more........... **$327**

#781 motor drive (291, 323, 4420) **89.95**
228 **Brass Refractor** **289.95**
290 2.4 Inch Equatorial **214.95**
291 2.4 Inch Deluxe Equatorial **269.95**
323 3.1 Inch Alt-Azimuth .... **CALL**

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- 5x21 erecting image finder
- 45° erecting diagonal
- 40x Meade eyepiece

$317

97ER-2 3½ Inch spotting scope as above but with rugged rubberized finish **$367**

Eyepieces (111x, 80x, 55x, 25x) **37.95**
Camera Adapter .. **34.95** Hard Case **44.95**
Hybrid Diagonal allows use of 1¼ eyepieces **48**

2045S 4" SPOTTING SCOPE

NEW 4 inch Schmidt Cassegrain with 40X eyepiece, 1¼" erecting diagonal& finder **$459**

4420 Newtonian

The Meade 4420 is the perfect telescope for the beginner. Its' large 4½ inch aperture optical tube & equatorial mounting make it ideal for planetary, deeper space observation or astrophotography.
Special Holiday Sale Price.......... **$294**

MTS-SN6 MCOG

SCHMIDT NEWTONIAN TELESCOPE

This Meade MTS-SN6 offers a superb 6 inch 750mm F/5 optical tube. It features **MCOG** multi-coated optics #788 motor drive, 1¼/2" focuser, 25mm eyepiece & sturdy MTS equatorial mount with pier.
Meade List Price
Focus Camera Sale Price **$599**

MTS-SN6 LX3

The perfect Newtonian for astrophotography. The MTS-SN6 LX3 is equipped with Meade's LX3 quartz drive & #36 Hand Controller for accurate guiding **$689**

MTS-SN8 MCOG

This is the telescope that discovered Comet Austin in 1989. It's 8" 812mm F/4 **multicoated optics** make it ideal for deep space photography., Add a 2x barlow lens & it becomes a superb planetary telescope. This full factory pack includes #788 motor drive, 1¼/2" focuser, 25mm eyepiece & sturdy MTS equatorial mount with pier.
Meade List Price Over $1300 **$729**
Focus Camera Sale Price.......

#66A Dec Arm .... **43** #66C Dec. Arm **57**
6x30 Finder .... **43** 8x50 Finder **69**
Basic Camera Adapter (SN6/SN8) **38.95**
#43 Drive Corrector & Inverter **87.95**

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DS-10A 10 INCH NEWTONIAN

10 inch 1150mm F/4.5 Deep-Space Newtonian complete with equatorial pier mount & stand, motor drive, 1¼/2" focuser, 25mm eyepiece, setting circles **$674**

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SUPER PLOSSL - Up to 52° Apparent Field
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32mm 1¼" .... **84.50** 40mm (44°AF) .. **87.50**
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Classic 8 is the latest in a long line of fine Schmidt-Cassegrain telescopes from the company that pioneered top quality comercial scopes. Its' fine 8 inch 2032mm F/10 optical tube is further enhanced by the application of Celestron's unique Starbright coating to provide optimum light transmission. Add to that a rugged equatorial mount and accurate motor drive and you have the perfect observing package for any astronomer, pro and novice alike.

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- 8 inch 2032mm F/10 optical tube with Starbright coatings for enhanced light transmission
- Celestron 30mm Plossl Eyepiece (instead of the lower grade Kellner eyepiece usually supplied)
- Celstron's latest model heavy duty adjustable field tripod (this is usually an additional cost option)
- Rugged swing fork equatorial mounting system with precise AC motor drive for tracking
- 6 x 30 Finderscope & 1¼" Star Diagonal
- Adjustable equatorial wedge

List Price Over $2400
FOCUS CAMERA'S PRICE $1199

SUPER POLARIS C8

COMPLETE PACKAGE INCLUDES:
8 inch 2032mm F/10 Schmidt-Cassegrain optical tube, Super Polaris equatorial mount with slow motion controls, 5x24 finder, 1¼" diagonal 25mm Kellner eyepiece & trunk case.
List Price Over $1700 **$989**

SUPER POLARIS C8 STARBRIGHT $1167

POWERSTAR PEC

The new Powerstar PEC features Celestron's famed 8 inch Schmidt Cassegrain optics with **Starbright** coatings, PEC periodic error correction DC servo drive system & Byers worm gear for improved tracking accuracy, 30mm Plossl eyepiece, 6x30 finderscope 1X" Star Diagonal, case, wedge & rubberized tripod **$1539**

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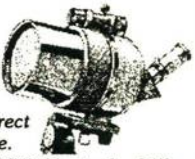

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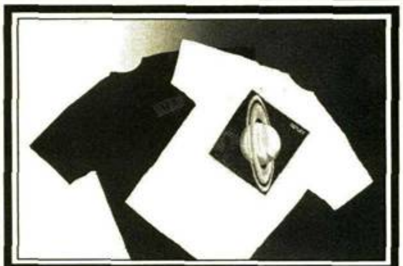

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Astronomy Books

A FINE HANDBOOK FOR SOLAR VIEWING

The New Observe and Understand the Sun, edited by Richard E. Hill, (Astronomical League, 4 Klopfer St., Pittsburgh, PA 15209; 1990), 63 pages, paperback, $5.00.

If you wish to learn about the astrophysics of the Sun, many books are available for professionals and lay readers. But if you want solid, detailed advice on observing the Sun with your backyard telescope — ah, that's a different matter and much harder to find. Precisely for that reason this new book is valuable.

A collection of 14 articles written by prominent amateur and professional solar observers, the book tells you how to observe the Sun, construct solar observation equipment, take solar photos, record your observations, and participate in useful research. (It is an updating of the Astronomical League's popular solar observing handbook, originally issued in 1976.)

In non-technical terms, experienced observers Walter Scott Houston, Walter Wheeler, and Fredrick Veio, describe various solar features and give you tips on safe solar observing. They also cover the types of commercially available solar filters, giving the advantages and disadvantages of each, and explain how to construct a solar viewing box that uses eyepiece projection.

Editor Richard Hill's articles discuss sunspot classification systems and how to construct Dobsonian and horizontal solar telescopes. (Telescopes designed for solar viewing perform better than converted nighttime scopes.) The horizontal telescope he describes uses mirrors to direct sunlight into a small telescope mounted inside a building. The Sun's image is then projected onto a screen or video camera.

For those who want to go beyond ordinary white-light solar observing, the last half of the book covers taking solar photographs, viewing the Sun in monochromatic light, and constructing solar spectroscopes. By following the instructions, you can build low-cost but efficient equipment.

This book is packed with helpful tips and ideas, going way beyond the coverage typically given in solar astrophysical books, in which the main emphasis falls on professional equipment. The book, aimed at the amateur solar observer, is written in non-technical language. I did find that the shortness of some articles left me wanting more information, but even so I highly recommend this handbook to anyone interested in observing the Sun. — *Robert A. Garfinkle*

Observing

The Trained Eye: an Introduction to Astronomical Observing, by Leon Palmer, (Saunders College Publishing, 1990), ISBN 0-03-047363-2, 274 pages, 8 fold-out maps, paperback, $9.50.

This is a laboratory manual and workbook for college students in introductory astronomy courses. It contains 18 projects, some designed for indoor use. For the most part, the workbook is self-contained but a few projects will require additional equipment such as a small telescope.

Exercises in Practical Astronomy Using Photographs, by M. T. Brück, (Adam Hilger, 1990), ISBN 0-7503-0061-2, 108 pages, sewn binding, hardcover, $37.00.

This book crams 33 projects into 108 pages. The topics include the Sun, asteroids, stars in motion, globular star clusters, interstellar reddening, nearby galaxies, and clusters of galaxies. Each exercise is completely self-contained.

Astronomy with Your Personal Computer, 2nd edition, by Peter Duffett-Smith, (Cambridge University Press, 1990), ISBN 0-521-38995-X (pbk), hardcover, 258 pages, sewn-binding, $59.50, paperback, $24.95.

First published in 1985, this handbook of BASIC programs has been expanded, revised, and updated. The new versions do more or run faster or contain more features than the old. However, because most programs had to be rewritten thoroughly to achieve this, the new programs are not compatible with the old versions.

The Solar System

Exploring the Reaches of the Solar System, by Ray Spangenburg and Diane Moser, (Facts on File, 1990), ISBN 0-8160-1850-2, 108 pages, hardcover, acid-free paper, $22.95.

Organized in solar system order (Mercury to Pluto) are chapters that explain the space probes that have visited each planet and moon. The text provides capsule data on each body and discusses what has been learned about it. Color photos are reproduced well, but most black and white photos appear out of focus or blurred.

General Astronomy

Astronomy Before the Telescope, vol. 2, by Nicholas T. Bobrovnikoff, (Pachart Publishing, 1990), ISBN 0-88126-226-9, 222 pages, paperback, $38.00.

This work surveys the astronomical knowledge of different ancient civilizations in regard to solar system bodies: the Sun, planets, comets, and meteors and meteorites. (Volume 1, on the Earth-Moon system, was published in 1986.)

QUICK PICKS

Observing

Young Astronomer's Guide to the Night Sky, by Michael Porcellino, (TAB Books, 1990), ISBN 0-8306-3495-9, 144 pages paperback, $12.95.

Interstellar Matter

Space Plasma, by Ya. L. Al'pert, (Cambridge University Press, 1990), ISBN 0-521-38971-2 and 0-521-38972-0, 2 volumes, 308 and 286 pages, paperback, $29.95 each volume.

Galactic and Intergalactic Magnetic Fields, edited by R. Beck, P. P. Kronberg, and R. Wielebinski, (Kluwer Academic, 1990), ISBN 0-7923-0704-6, 540 pages, acid-free paper, $127.

Dark Matter in the Universe, edited by P. Galeotti and D. N. Schramm, (Kluwer Academic, 1990), ISBN 0-7923-0575-2, 303 pages, acid-free paper, hardcover, $87.

Dark Matter in the Universe, edited by H. Sato and H. Kodama, (Springer-Verlag, 1990), ISBN 0-387-51936-X, 137 pages, acid-free paper, hardcover, $57.70.

Galaxies

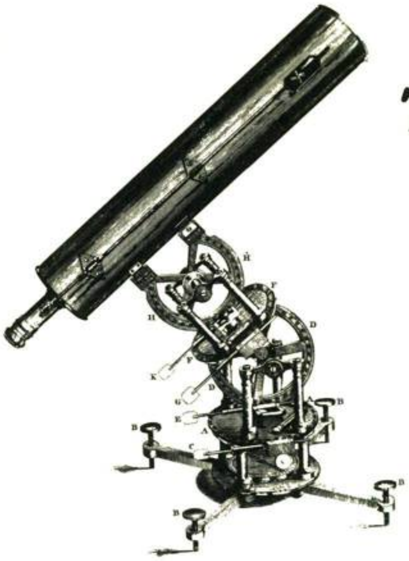
Dynamics and Interactions of Galaxies, edited by Roland Wielen, (Springer-Verlag, 1990), ISBN 0-387-51941-6, 518 pages, acid-free paper, hardcover, $77.60.

Clusters of Galaxies, edited by W. R. Oegerle, M. J. Fitchett, and L. Danly, (Cambridge University Press, 1990), ISBN 0-521-38462-1, 395 pages, hardcover, $54.50.

Astronautics and Space

Global Environmental Change: the Role of Space in Understanding Earth, edited by Richard G. Johnson, (American Astronautical Society, 1990), ISBN 0-87703-323-4, 167 pages, paperback, no price given.

Guidance and Control 1990, edited by Robert D. Culp and A. D. Gravseth, (American Astronautical Society, 1990), ISBN 0-87703-321-8, 660 pages, paperback, no price given. ☐



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PRESERVING THE PAST IN THE PRESENT FOR THE FUTURE

That's essentially what our forthcoming May 18th auction is all about — the preservation of days gone by for us in the present generation and future generations to enjoy. All the legends will be here at the auction: Fitz, Clark, Mogey, Brashear, Zeiss, Ingalls, Porter, Herschel, Flammarion, Serviss, and many others. They live on in the telescopes and accessories they created, or in their words with papers, letters and books. The shades of the past seem to come alive as we attempt to contemplate the wide variety of astronomical and optical items we have gathered for this occasion. All this comes together in what may be the largest event of its kind ever held.

Breathtaking items — 13″ Clark Refractor at Columbia, 9¾″ Fitz-Clark from West Point, 8⅓″ f/21.8 Troughton & Simms, Dollond Twin Telescopes, over 100 binoculars and microscopes, over 100 books from 1561, paintings, earliest known celestial maps, signed Herschel letter, equinoctial dials, spectroscopes, surveying instruments, 1/16″ scale replica of 200″ Palomar, 1896 Mars globe with canals, telescopes up to 18″, many Zeiss items, so much more.

The auction will commence at 11 AM on Sat., May 18th. Preview is Fri. 7-9 PM and Sat. 9-11 AM. Mail or absentee bids will be accepted and three lines are available for telephone bids. Length of sale, about 5-6 hrs. The auction will be held at Mapes Auction Gallery in Vestal, New York, located 9 miles east of Owego or 2 miles west of Vestal on Route 434. Exact directions and a list of nearby motels are included in the auction catalog. Broome Co. Airport in Binghamton is 20 minutes from the gallery.

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DEC. MOTOR		FOCUS MOTOR	
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IDAI 4.5" f/7.8 (860mm focal leng.) w/Matching Elliptical Flats	**64.95**
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The Stereo Binocular Viewer allows you to adopt two eyepieces to the telescope for simultaneous viewing (i.e., like binoculars). The result: a three dimensional effect when observing many celestial objects.

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This special purpose eyepiece includes a double-line reticle pattern, internally illuminated so that the lines are clearly visible against a dark sky. The illuminated system consists of a red LED. A variable illumination control permits adjustment of the brightness from bright to dim to match different guiding requirements. With 6 feet cable that plugs in the drive base of Mead LX3, 5, 6 and Premier. **79^{95}**

Above reticle with a Remote Battery Pack (uses 9 Volt Battery – not included) for non Meade type of drive bases .... (MDIREP10) **89.95**

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The Deluxe Tripod Slow Motion controls fit on top of any standard photo tripod and has a large stable base with a standard size 1/4x20 mounting screw. (CNSMC) **46^{95}**

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Tele Extender for Eyepiece projection photography. Fits Celestron / Meade **24.95**

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Off Axis Guider System
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CELESTRON

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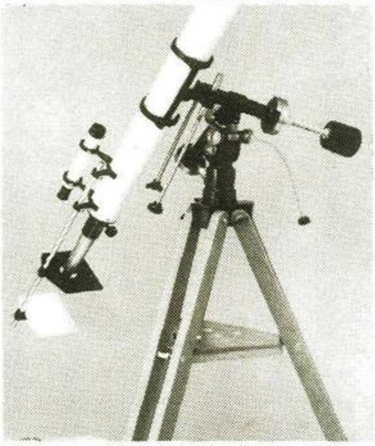

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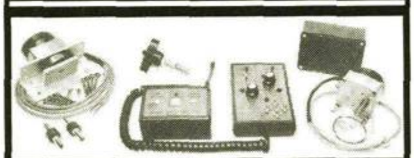

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Meetings & Events

June 10-12
Society of Amateur Radio Astronomy Conference, National Radio Astronomy Observatory, Green Bank, West Virginia. Contact: S.A.R.A., 247 North Linden Street, Massapequa, NY 11758. Phone: (516) 798-8459.

June 13-15
Astronomical League Mid-States Regional Convention, Wichita, Kansas. Contact: Kansas Astronomical Observers, P. O. Box 49013, Wichita, KS 67201.

June 14-15
21st Annual Apollo Rendezvous and Telescope Fair, Dayton, Ohio. Sponsored by the Miami Valley Astronomical Society and the Dayton Museum of Natural History. Contact: Ian Dumbauld, 5932 Culzean Drive Apt. 706, Trotwood, OH 45426. Phone: (513) 256-0673 (Woody Markland).

June 14-15
6th Annual Sedona-Verde Valley Astrophotography Festival, two hours from Phoenix, Arizona. Sponsored by Rainbow's American Dream. Contact: Russell Nidey, 1101 Zalesky Road, Cottonwood, AZ 86326. Phone: (602) 634-7332.

June 14-16
Arkansas Star Party, Coleman Memorial Observatory, near Ft. Smith, Arkansas. Sponsored by the Arkansas-Oklahoma Astronomical Society. Contact: Coleman Memorial Observatory, Route 1, Box 404, Hackett, AR 72937.

June 14-16
Astronomy Weekend '91, Martz Observatory, Frewsburg, New York. Contact: Astronomy Weekend '91, c/o Tom Bemus, RD #3 Box 161A, Bemus Point, NY 14712. Phone: (716) 483-0343 (days), (716) 386-4566 (evenings).

June 14-16
Jersey Star Quest, Beemerville 4-H Camp, Sussex, New Jersey. Sponsored by the Amateur Astronomers Association of Princeton, Inc. Contact: Greg Mauro, Registration Chairman, P. O. Box 2017, Princeton, NJ 08543. Phone: (609) 490-3560 (days).

June 14-16
Mason-Dixon Star Party, Spring Valley County Park, York, Pennsylvania. Contact: Jeri Jones, York County Parks Astronomical Society, 400 Mundis Race Road, York, PA 17402. Phone: (717) 771-9440 (days), (717) 225-3744 (evenings).

June 14-16
4th Annual Wisconsin Observers' Weekend, Hartman Creek State Park, Waupaca, Wisconsin. Sponsored by the Northeast Wisconsin Stargazers. Contact: Don Wyman, 1815 Kienast Avenue, Oshkosh, WI 54901. Phone: (414) 233-3083 (evenings).

June 15
Astronomy Convention, Hiram College, Hiram, Ohio. Sponsored by the Ohio Turnpike Amateur Astronomers. Contact: Dawn Jenkins, 1494 Lakeland Avenue, Lakewood, OH 44107. Phone: (216) 521-5115.

June 15-17
Star Gazing Expedition, White Mountains, California. Sponsored by the Santa Monica Amateur Astronomy Club. Contact: Robert Lozano, 1415 Michigan Avenue, Santa Monica, CA 90404. Phone: (213) 450-1944.

June 16
Prairie Song Star Party, Bartlesville, Oklahoma. Sponsored by the Bartlesville Astronomical Society. Contact: Ken Willcox, 225 SE Fenway Place, Bartlesville, OK 74006. Phone: (918) 336-9900 (days), (918) 333-1966 (evenings).

June 22-23
The Universe in the Classroom, University of Wyoming, Laramie, Wyoming. Contact: Astronomical Society of the Pacific, Teachers' Workshop Information, 390 Ashton Avenue, San Francisco, CA 94112.

June 22-27
Astronomical Society of the Pacific National Meeting, University of Wyoming, Laramie, Wyoming. Contact: Astronomical Society of the Pacific, Wyoming Meeting Information, 390 Ashton Avenue, San Francisco, CA 94112.

July 8-12
Association of Lunar and Planetary Observers Convention, La Paz, Baja California Sur, Mexico. Contact: ALPO, P. O. Box 143, Heber Springs, AR 72543. Phone (501) 362-7624. ☐

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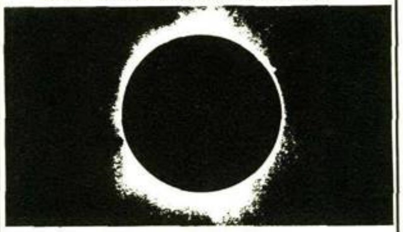

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Readings and Resources

Binary Stars *(page 34)*

Protostars and Planets II, edited by David C. Black and Mildred S. Matthews, (University of Arizona Press, 1985). A compendium of technical papers summarizing the state of research on star formation as of 1984. Worth looking for in a large library; many papers are accessible to lay readers, at least in their essence. *(Protostars and Planets III* is due to be published this year.)

Observing Visual Double Stars, by Paul Couteau, (MIT Press, 1981). Compact and useful guide for backyard observers who want to explore the realm of double stars with their telescopes.

Travel Tips for the Big Eclipse *(page 68)*

"Journey Into Darkness" by Alan Dyer, ASTRONOMY, July 1990. About the eclipse, where it will be visible, and how to get there.

"How to Photograph the Eclipse" by Alan Dyer, ASTRONOMY, April 1991. Instructions for different techniques for capturing the partial and total eclipse phases on film.

Dance of the Jovian Moons *(page 76)*

"Watch Jupiter's Moons Play Tag," by John E. Westfall, ASTRONOMY, January 1991. An overview of the entire series of mutual eclipses and occultations.

CREDITS

Cover: courtesy Canada-France-Hawaii-Telescope Corporation, T. Gregory, photographer; *p. 4:* Terence Dickinson, 35mm lens at f/2, 2-minute guided exposure, Kodachrome 200, taken December 13, 1990; *p. 24,* European Southern Observatory, Danish 1.54-meter telescope, 7-hour exposure; *p. 26, top:* courtesy Richard Ellis, Jeremy Allington-Smith, and Ian Smail, University of Durham; *bottom:* courtesy European Southern Observatory; *p. 28:* Richard Berry; *p. 30, top:* January 17 CRRES lithium cloud photo by Patti Wheaton, Technology International Corp., courtesy NASA; *bottom:* January16 CRRES barium cloud photo by Gregory Gage, 50mm lens, f/2.8, 30-second exposure, Kodacolor 400 Gold film; *pp. 34-35:* painting by Bob Eggleton; *pp. 36-41:* all images courtesy Alan P. Boss; *pp. 42-49:* all ROSAT images copyright Max Planck Institut für Physik und Astrophysik, Institut für extraterrestrische Physik; *p. 42:* Large Magellanic Cloud visible-light photo courtesy Cerro Tololo Inter-American Observatory, 61cm Schmidt camera; *p. 44:* Orion photo by Alfred Lilge, Ektachrome 200 film, 30-minute exposure; *p. 50:* illustration by Bruce Bond; *p. 65:* Mace Hooley, 8-inch f/1.5 Schmidt camera, Fujichrome 100 film, 15-minute exposure; *p. 69:* all photos by Richard Berry; *p. 69, background eclipse photo:* Jacques Guertin, November 23, 1984, Papua New Guinea; *p. 70:* all photos by Joel Harris; *p. 71:* map art by Tom Hunt; *p. 72:* map art by Tom Hunt; *p. 73, top two photos:* Alan Dyer; *p. 73, bottom two photos:* Gary Bird, Edmonton Space and Science Centre; *p. 75:* Ernest Piini; *p. 80:* Rick Schrantz, 10-inch SCT at f/6, hypered Tech Pan film, 70-minute exposure; *p. 81, top:* Tom Eby, 8-inch SCT at f/5.6, hypered Tech Pan film, 45-minute exposure; *bottom:* Martin C. Germano, 8-inch f/5 reflector, hypered Tech Pan film, 60-minute exposure; *p. 82:* Tony Hallas and Daphne Mount; *p. 83, top:* Joe Liddell, 17.5-inch f/4.5 reflector, 3M 400 film, 30-minute exposure; *bottom:* Tony Hallas and Daphne Mount; *p. 84:* Darla Gawelski; *p. 85 (top and middle):* Darla Gawelski; *bottom:* Moon and star trail photos by Alan Dyer, with Meade 2045; *p. 86:* Darla Gawelski; *p. 89 top:* Fred W. Price, 8-inch reflector at 224x with orange filter and apodising screen on November 21, 1990; *left center:* Jose Olivarez, 10-inch reflector at 171x and 245x with orange filter on December 10, 1990; *right center:* Jose Olivarez, 10-inch reflector at 153x with orange filter on November 17, 1990; *bottom left:* Fred W. Price, 8-inch at 224x with orange filter and apodising screen on November 9, 1990; *bottom right:* Fred W. Price, 8-inch reflector at 224x with orange filter on November 30, 1990; *p. 90, top left:* Chris Schur, 8-inch f/1.5 Schmidt camera, Tech Pan film, 5-minute exposure on February 9, 1991, *bottom left:* Joseph C. Petrillo, 300mm lens at f/5.6, Ektar 1000 film, 3-minute exposure on February 3, 1991, *top right:* Chris Schur, 8-inch f/1.5 Schmidt camera, hypered Tech Pan film, 25-minute exposure with deep blue filter on January 10, 1991; *pp. 90-91, sequence:* Donald C. Parker, — image processing by Richard Berry; *p. 92, top:* Ronald E. Royer, 105mm f/2.5 lens, Fujichrome 1600D film, 20-minute exposure on January 11, 1991; *p. 93:* Jim Fantozzi; *p. 94, top left:* Bill and Sally Fletcher, 16-inch f/4.5 reflector, hypered Fujichrome Super HG 400 film; *bottom left:* Richard Andreassen, 55mm f/1.8 lens, Ektachrome 200 film pushed to ISO 400, 10-minute exposure; *top right:* George E. Fowler, 14-inch f/11 SCT, Photometrics STAR-I CCD, 30-second exposure; *bottom right:* Michael Stecker and James R. Foster, 180mm f/2.5 lens, hypered Tech Pan film, 120-minute exposure with H-alpha filter.

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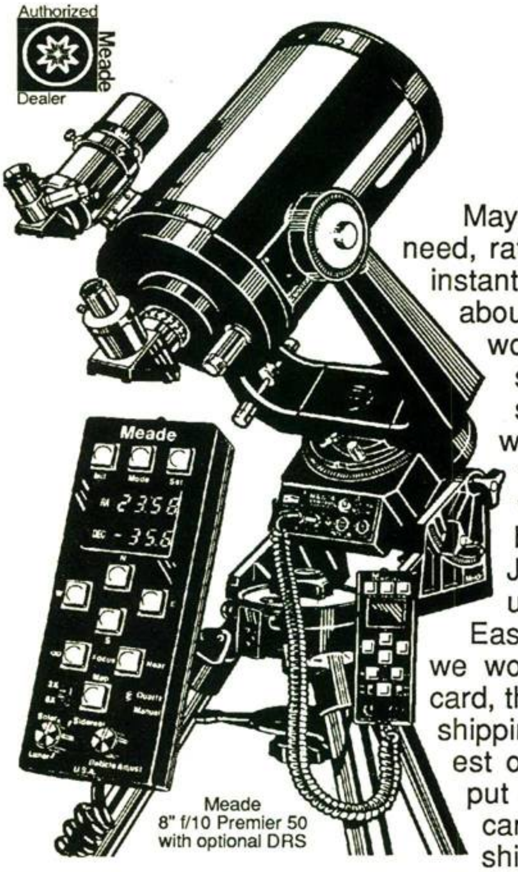

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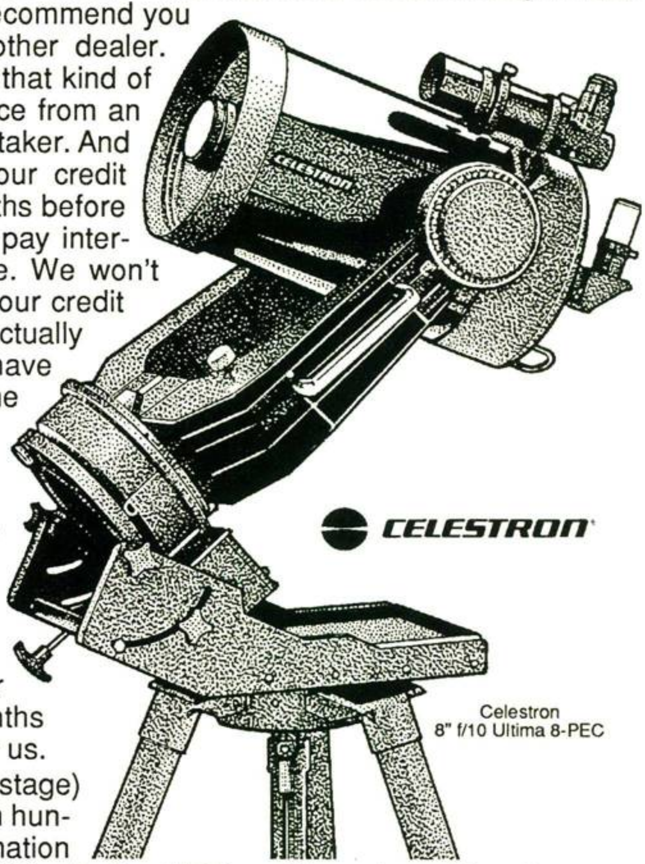

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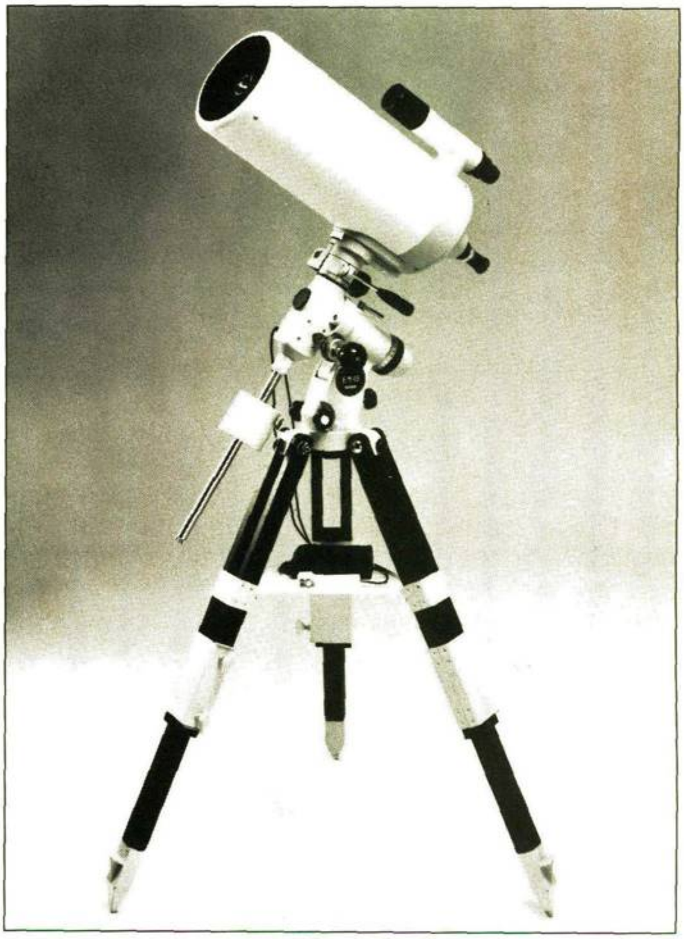

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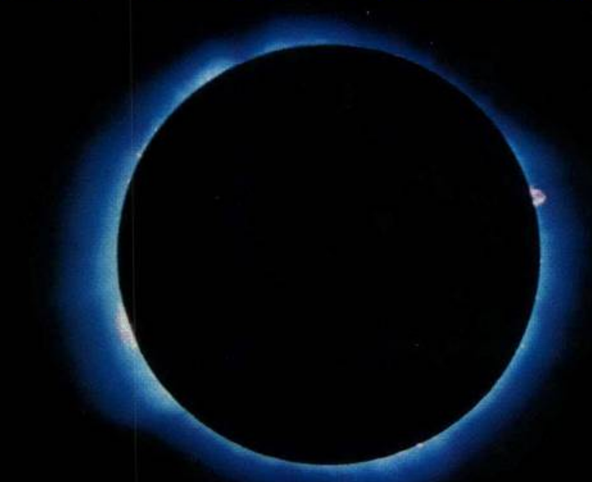
On July 11, 1991 Will You Get Caught In The DARK?



You will if you're on a **ROYAL CARIBBEAN** cruise ship lounging in the Pacific, courtesy of Future Trends Software. This is just one of thousands of dollars worth of prizes being given away to registered owners of EZCosmos 3.0.

EZCosmos reveals the entire celestial sphere for any date, time and location from 4000 B.C. to 10000 A.D. You can choose your location from one of 1150 cities around the world, or you can input your own latitude and longitude to see the sky from anywhere on Earth.

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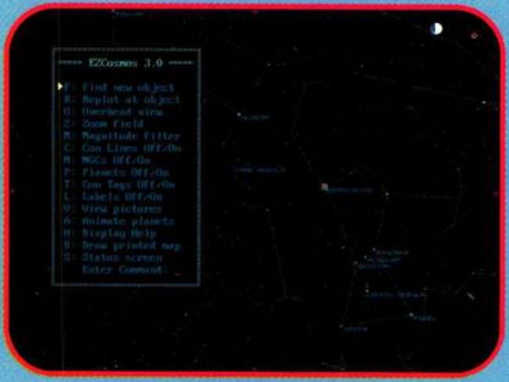
===== EZCosmos 3.0 =====
F: Find new object
R: Replot at object
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Enter Command: _

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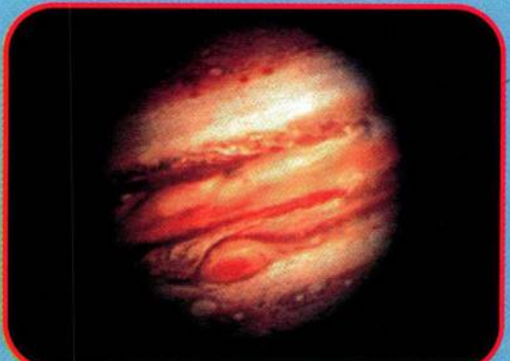

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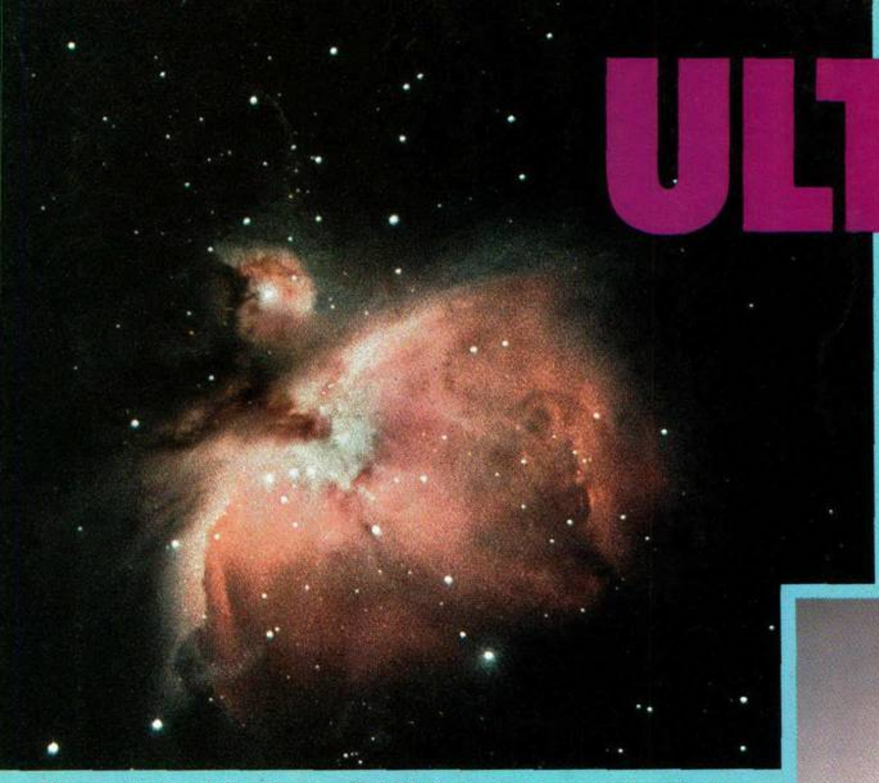
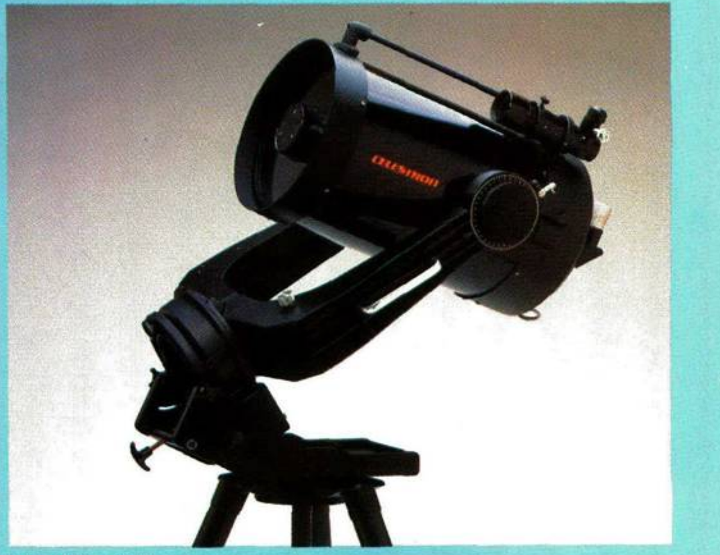
ULTIMA® 11

The Best of Both Worlds f/10 & f/6.3



CII photo by Jim Riffle, Cloudcroft, NM. 5-minute exposure using Konica 3200 film at f/6.3



The Ultima® 11

CELESTRON ULTIMA® 11 TELESCOPE

Since the introduction of this superb telescope in September 1989, there have been few follow-up ads. Why? The Ultima® 11 was received with an unprecedented demand that far exceeded our most optimistic projections. Since then our manufacturing capacity has been doubled and redoubled so that now we can offer this instrument for timely delivery.

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OPTICAL COATINGS – Celestron's Starbright® coating group produces the highest throughput transmission in the industry.

ENGINEERING EXCELLENCE – A massive design with heavy duty forks, polar shaft, large setting circles, wedge and tripod. Usable in both hemispheres.

DRIVE GEAR SYSTEM – The most advanced, most accurate in the industry. Utilizes the 7.54″ diameter 359-tooth Byers worm gear system. *Sky & Telescope* notes in its test of the Ultima drive, ". . .at a mere 19 arc seconds, the drive error was the least I have ever seen in a mass-market telescope."

Ultima® 11-PEC drive base

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